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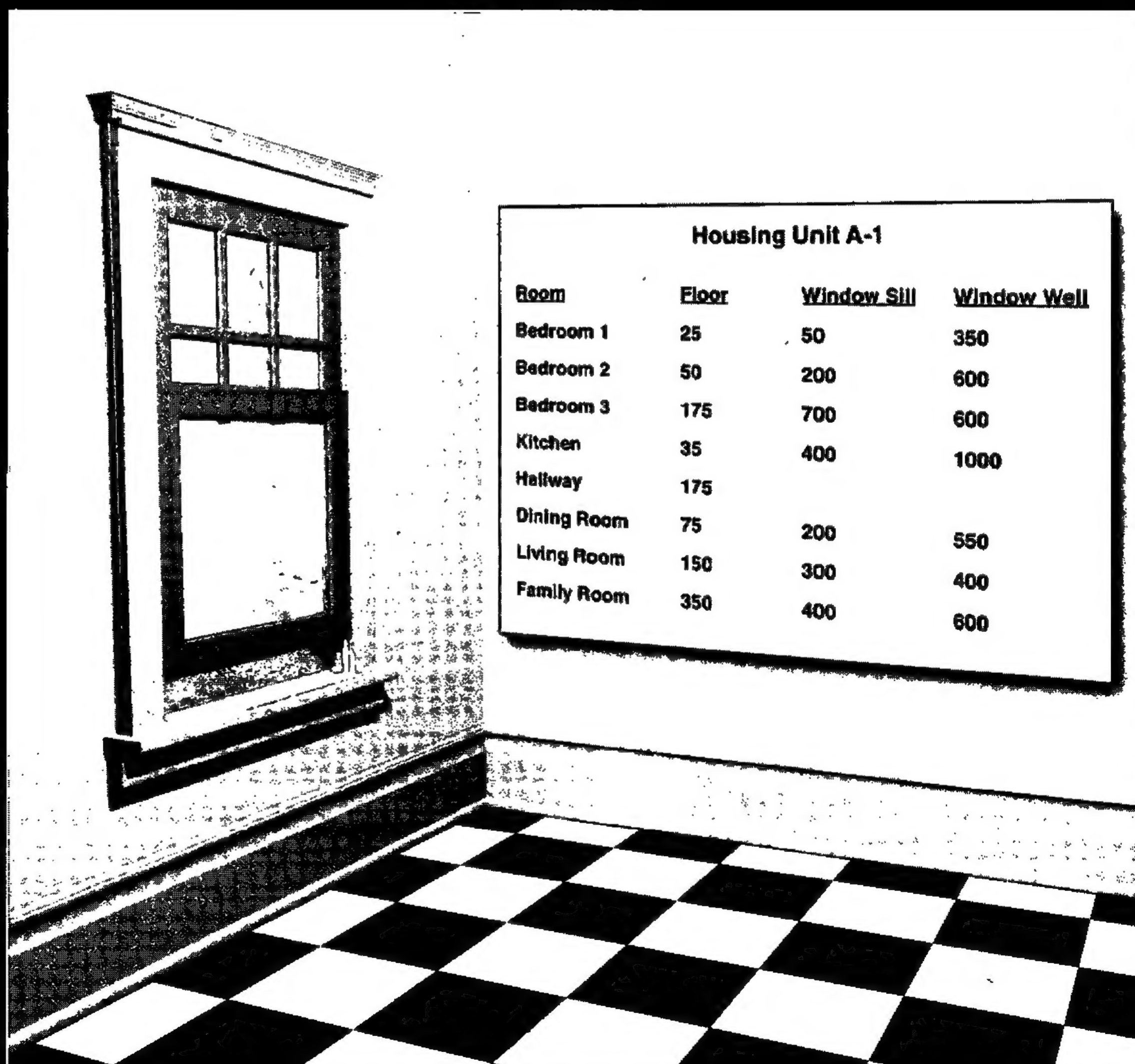
Analysis of Lead Dust Clearance Testing



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Analysis of Lead Dust Clearance Testing

FINAL REPORT

Program Assessment and Outreach Branch
National Program Chemicals Division
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
Washington, D.C. 20460

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FURTHER INFORMATION

Information about other technical reports on lead can be found through the internet at the address: http://www.epa.gov/lead.

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CONTRIBUTING ORGANIZATIONS

The methodology described in this report is part of a task funded by the U.S. Environmental Protection Agency. The task was managed by the U.S. Environmental Protection Agency. The task was conducted by Battelle Memorial Institute under contract with the U.S. Environmental Protection Agency.

Battelle Memorial Institute

Battelle Memorial Institute (Battelle) was responsible for acquisition of the data, data management, development of statistical methods, and the writing of this report. The key Battelle staff were Dr. Bradley Skarpness, Mr. Ying-Liang Chou, and Mr. Warren Strauss. Contributing staff were Ms. Jennifer Holdcraft, Ms. Pamela Hartford and Mr. Matt Palmgren.

U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) funded the task, managed the task, reviewed task documents, and managed the peer review of this report. The EPA Work Assignment Manager was John Schwemberger. The Project Officer was Sineta Wooten.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) gathered data about local clearance dust results to characterize and assess the likelihood of achieving the HUD Interim Guidelines Clearance Standards for a wide variety of housing units, components, and surface types. The EPA obtained dust lead loading results from lead clearance dust wipe samples from three federally funded projects: the Federal Housing Authority (FHA) and Public Housing Authority (PHA) Lead-Based Paint Abatement Demonstration projects sponsored by the Department of Housing and Urban Development (HUD) and HUD's Lead-Based Paint Hazard Control Grant Program (HUD Grantee program), and from four state or local government authorities: the Maryland Department of the Environment (MDE); Atlantic City Housing Authority, New Jersey; Dover Housing Authority, New Hampshire; and the Cleveland Lead Hazard Abatement Center, Ohio.

The results presented in this report represent lead clearance testing activities that occurred between 1989 and 1999 under the 1990 HUD Interim Guidelines [2], which set lead clearance dust wipe standards at 200 $\mu g/ft^2$ for bare floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. (These standards contrast with the 2001 EPA final dust-lead clearance standards of 40, 250, and 400 $\mu g/ft^2$, respectively [1].) The collected data include 39,301 lead clearance dust wipe sample measurements taken on floors, window sills, and window troughs from 4,518 single or multi-unit family housing units that had received some type of lead-based paint abatement or other intervention. The samples were taken over a number of site visits since a housing unit would be retested if at least one individual dust wipe sample had a lead-loading result greater than the HUD Interim Guidelines Clearance Standards. Although the percentage of individual dust wipe clearance sample results that passed clearance was above 90% for all three surface areas, on average only 67% of the housing units passed clearance on the first site visit. This indicates that the individual samples that fail clearance are not necessarily concentrated in just a few homes. Eventually 4,095 housing units out of 4,518 (87%) were known to have passed clearance. Information on most of the remaining 13% of the housing units was lost during follow-up ("lost to follow-up"), although some units might have simply failed clearance after multiple attempts. It is likely that many of the units lost to follow-up eventually cleared, although this assumption was not included in the data analysis. The losses to follow-up may be

attributed to families moving, litigation, or poor record keeping, or the fact that housing units were still being retested at the time of data collection.

These data represent extensive dust-lead clearance testing, with results collected from across the United States. Similar trends were observed in individual data sources. For example, the distribution of clearance lead-loading results within each source of data was highly skewed to high values, so a (natural) log transformation was applied to these results, which resulted in a log normal distribution and was used in the analyses in this report. In general, floor dust wipe samples had a smaller geometric mean lead loading than window sills, which in turn had a smaller geometric mean than window troughs. The geometric mean lead loading of the samples collected within each component type generally increased from the first site visit to the third site visit, since generally only homes that failed clearance testing were resampled in subsequent site visits. For surfaces that failed clearance, it is presumed that they were re-cleaned prior to re-testing in subsequent site visits. The variability of lead-loading results within a house was slightly smaller than the variability of lead-loading results between houses for most data sources. The pairwise correlations between floor, window sill, and window trough lead-loading results of samples collected from within the same room during the first site visit were positive and statistically significant. The correlation between window trough and window sill samples from within the same room was highest among the three component types. Floor and window sill dust wipe results had a slightly stronger correlation than floors and window troughs.

In general, accounting for longitudinal trends in a dataset is a difficult task even when the data are collected under controlled conditions. The precise circumstances under which most of these observational data were collected within each data source were very diverse and in many cases did not span many years. Subsequently, only the Maryland Department of the Environment data source was analyzed for longitudinal trends (Appendix A). These data spanned five years, 1991-1995, and contained the largest number of housing units, 706, which could be analyzed for trends over time. This analysis indicated no significant differences between the geometric means of components across the years using 95% confidence intervals.

The HUD Guidelines [3] and 40 CFR Part 745 [1,4] indicate that composite samples of up to four individual dust wipes collected from different locations of the same component type within a housing unit can be analyzed together to yield a single dust lead-loading result for clearance testing. To evaluate how composite sampling would affect clearance, composite

sampling was simulated by grouping individual clearance dust wipe results. Pass/fail rates of housing units associated with composite samples are different from those associated with individual samples. Simulations indicated that composite sampling decreases the probability of a dwelling failing, if at least one of the individual sample results was above the HUD Interim Guidelines Clearance Standard. The simulations were based on simulated composite samples constructed from measured individual lead-loading clearance testing results. Since lowering the HUD Interim Guidelines Clearance Standard associated with composite dust-wipe samples for each component type increases the sensitivity (the probability of a dwelling unit failing clearance based on simulated composite samples given that the unit would also have failed clearance based on the individual samples), two other clearance criteria with lower levels (Standard/n Rule and 2 x Standard/n Rule)[1] were defined and compared. The Standard/n criterion resulted in fewer false clearance passes than the HUD Interim Guidelines Clearance Standard in the simulation study, at the expense of increasing false clearance failures. The 2x Standard/n criterion struck a balance between the other two criteria.

In addition to the above results and conclusions, the following are some of the results and conclusions drawn from the data in response to specific questions. Table ES-1 is the tabular display and Figures ES-1 and ES-2 are the graphical illustrations for the first three questions.

What Lead Levels For Floors, Window Sills, and Window Troughs Are Typical in Dust Clearance Testing?

As seen in Table ES-1, the range of geometric means across the eight data sources[2] used in this report were 8.8 to 57.6 μg/ft² for bare floors, 11.3 to 461.6 μg/ft² for sills, and 15.8 to 393.3 for troughs during the first clearance site visit. The high window sill dust-lead loading of

[1]A Standard/n Rule allows a composite sample to pass clearance only if the lead loading result is less than the corresponding standard for individual samples divided by the number of subsamples in the composite sample. A 2×Standard/n Rule's clearance standard is the corresponding individual sample clearance criterion multiplied by 2/n, where n is the number of subsamples in the composite sample.

[2]Eight data sources were Maryland Department of the Environment, HUD FHA study, HUD PHA study, HUD Grantee program - high group, HUD Grantee program - low group, Atlantic City Housing Authority, Cleveland Lead Hazard Abatement Center, and Dover Housing Authority. Among 14 grantees participating in the HUD Grantee Program, 9 grantees used 200 μg/ft² and 5 grantees used 100 μg/ft² or 80 μg/ft² as clearance standards for floors. This report labeled "HUD Grantee (High)" for those 9 grantees that used 200 μg/ft² as clearance standards for floors and labeled "HUD Grantee (Low)" for those 5 grantees that used 100 μg/ft² or 80 μg/ft² as clearance standards for floors. Analyses were performed separately for these two groups.

461.6 μg/ft² may be due to the interior renovation strategy used in Dover, New Hampshire (excluding Dover data, the range of window sill geometric mean dust-lead loading was 11.3 to 60.3 μg/ft²). The 90th percentiles for dust-lead loading clearance sample results from the first site visit were between 68 and 418 μg/ft², 171 and 1624 μg/ft², and 137 and 5810 μg/ft², for bare floors, window sills, and window troughs, respectively (excluding Dover data, the range for the 90th percentile window sill dust-lead loading was 171 to 714 μg/ft²). The 90th percentiles for dust wipe clearance sample results from houses that passed clearance for standards of 200 μg/ft², 500 μg/ft², and 800 μg/ft² were between 57 and 141 μg/ft², 141 and 443 μg/ft², and 111 and 598 μg/ft², for bare floors, window sills, and window troughs, respectively.

Are Window Sills Being Cleaned to the Same Level as Bare Floors?

Table ES-1 shows that the geometric mean for the initial clearance test for floors was between 8.8 and 57.6 μg/ft²; for window sills it was between 11.3 and 461.6 μg/ft² (or 11.3 and 60.3 μg/ft² excluding Dover's window sill data). The 50th percentile for the first clearance test was between 5 and 48 μg/ft² for floors, and between 17 and 52 μg/ft² for window sills (excluding Dover window sill data). The 90th percentile was between 68 and 418 μg/ft² for floors and between 171 and 714 μg/ft² for sills (excluding Dover window sill data). For dust wipe clearance sample results from houses that passed clearance for the standards of 200 μg/ft² and 500 μg/ft² for floors and window sills, respectively: the 50th percentile was between 5 and 43 μg/ft² for floors, and between 17 and 47 μg/ft² for window sills (excluding Dover window sill data); the 90th percentile was between 57 and 141 μg/ft² for floors and between 141 and 263 μg/ft² for sills (excluding Dover window sill data). These results indicate that window sills tended to have somewhat higher lead levels than floors after intervention and cleaning.

Are Window Troughs Being Cleaned to the Same Level as Window Sills?

Table ES-1 shows that the geometric mean for troughs on the initial clearance test was between 15.8 and 393.3 μg/ft²; for sills the corresponding figures were between 11.3 and 60.3 μg/ft² (excluding Dover's window sill data). The 50th percentile for troughs at the initial clearance test was between 7 and 375 μg/ft²; for sills it was between 17 and 52 μg/ft²; the 90th percentiles were between 137 and 5810 μg/ft² for troughs and between 171 and 714 μg/ft² for sills (all excluding Dover window sill data). For dust wipe clearance sample results from houses

that passed clearance for the standards of 500 µg/ft² and 800 µg/ft² for window sills and window troughs, respectively: the 50th percentile for troughs was between 7 and 169 µg/ft², for sills it was between 17 and 47 µg/ft² (excluding Dover window sill data); the 90th percentiles were between 111 and 598 µg/ft² for troughs and between 141 and 263 µg/ft² for sills (all excluding Dover window sill data). These results indicate that window troughs tended to have higher lead levels than window sills after intervention and cleaning.

Do Window Sills and Window Troughs, Bare Floors and Window Troughs, or Bare Floors and Window Sills Pass Clearance Together or Fail Clearance Together?

If a dust wipe lead loading collected from a component (bare floors, window sills, or window troughs) passed its clearance standard, there was a good chance the other components in the same area passed. These probabilities were generally greater than 90%. For example, the probability that a window sill sample passed clearance given the window trough sample passed clearance was greater than 92% from almost all data sources presented in this report.

If one component failed its standard, it was not necessarily the case that another component in the same area (i.e., room equivalent) failed its standard. The probability that one component failed given another had failed in the same area ranged from 0% to 79%. Generally, these probabilities were under 30%. The exception occurred for the probability of a window sill failing clearance given the window trough failed clearance. This estimated probability was greater than 72% for some data sources.

Does Increasing the Number of Samples Taken Per Unit Increase the Probability of Failure for the Whole Unit?

Based only on the first site visit, as the number of samples taken within a given housing unit increased, the chance of this given housing unit failing clearance increased. This could be due to more samples being taken in the housing units that needed the most work or due to the use of maximum of dust results as the criteria for passing or failing clearance. Based on the logistic regression model results, the increase was statistically significant. The estimated average probability of clearance failure (across eight data sources) was 20% for two samples collected from floors. It increased to 22% when four samples were collected from floors and to 24% when six samples were collected from floors. For samples collected from window sills, the estimated

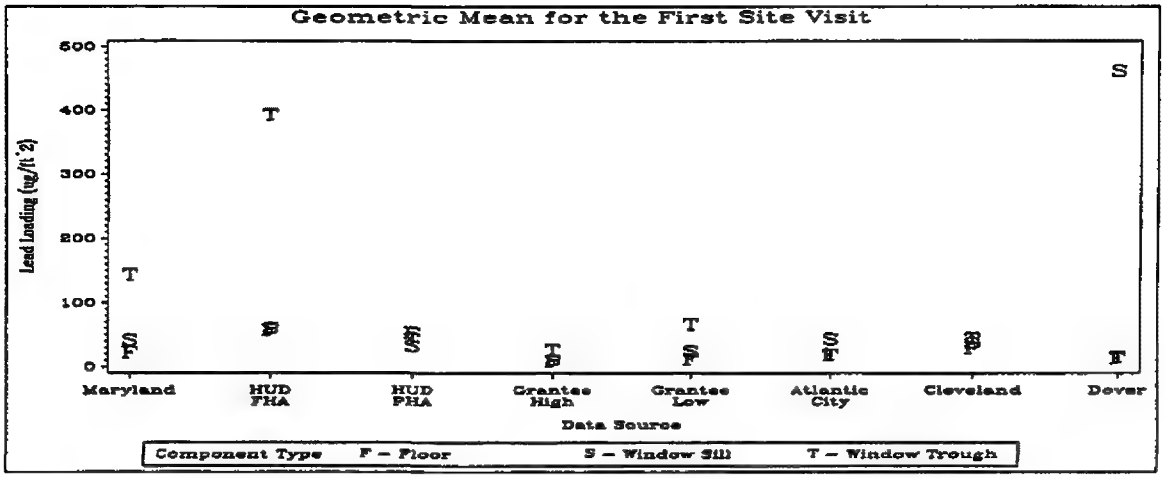
average probability of failing clearance was 23% when two sill samples were collected; it increased to 29% when four sill samples were collected and to 38% when six sill samples were collected. For samples collected from window troughs, the estimated average probability of failing clearance was 14%, 19%, and 29% when two, four, and six window trough samples were collected, respectively.

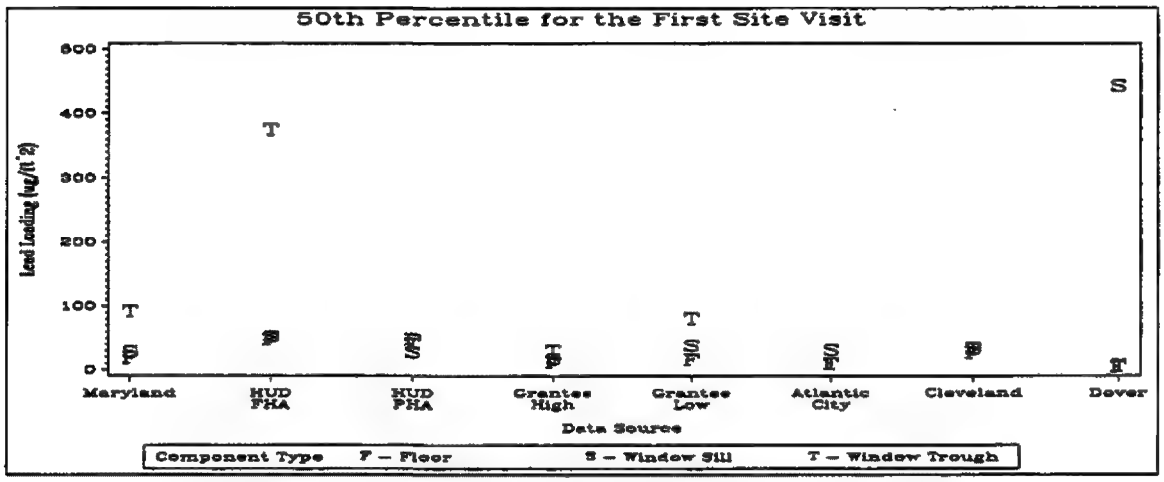
Table ES-1. Geometric Mean, and 50th and 90th Percentiles for the First Site Visit, and the 50th and 90th Percentiles for the Passed Clearance Visit, by Data Source and Component Type

Data Source	Geometric Mean for the First Site Visit			50th Percentile for the First Site Visit			90th Percentile for the First Site Visit			50th Percentile for the Passed Clearance Visit			90th Percentile for the Passed Clearance Visit		
	Floor	Window Sill	Window Trough	Floor	Window Sill	Window Trough	Floor	Window Sill	Window Trough	Floor	Window Sill	Window Trough	Floor	Window Sill	Window Trough
Maryland	22.4	41.7	144.2	19	28	92	181	511	3124	16	21	50	98	201	400
HUD FHA	57.6	60.3	393.3	48	52	375	418	714	5810	40	47	169	141	263	598
HUD PHA	52.9	32.7	43.5	48	28	42	200	175	167	43	27	41	118	150	138
HUD Grantee (High)*	8.8	11.3	26.5	12	17	30	110	202	396	12	17	27	70	141	237
HUD Grantee (Low)**	12.3	24.9	66.5	16	38	81	76	171	692	15	36	68	57	145	346
Atlantic City	18.5	43.1	19.4	10	31	10	130	380	190	10	30	10	80	180	170
Cleveland	29.7	37.8	44.7	27	33	33	190	190	530	20	33	33	78	170	490
Dover	13.5	461.6	15.8	5	443	7	68	1624	137	5	361	7	61	443	111

* Grantee that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantee that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.





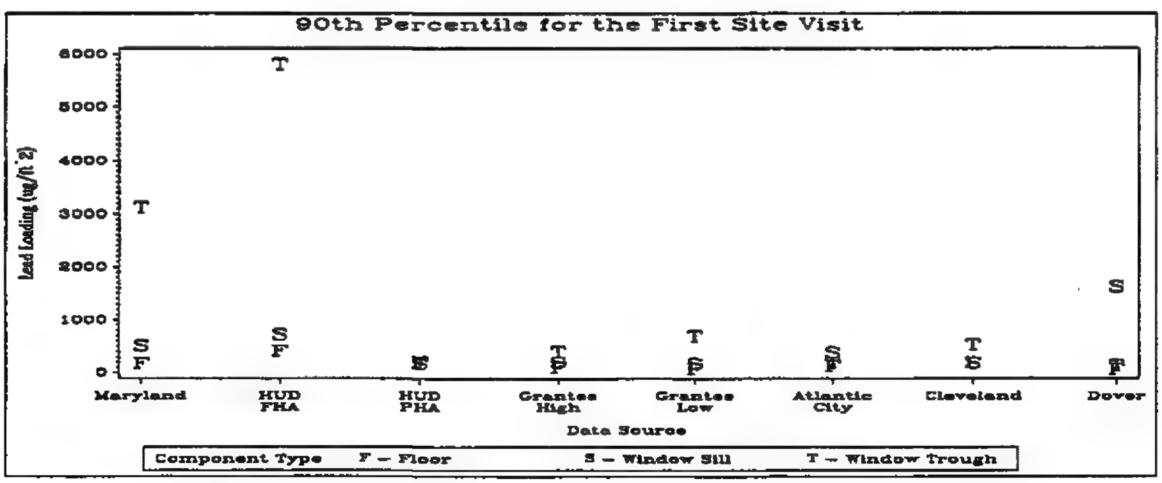


Figure ES-1. Geometric Mean, and the 50th and 90th Percentiles for the First Site Visit, by Data Source and Component Type

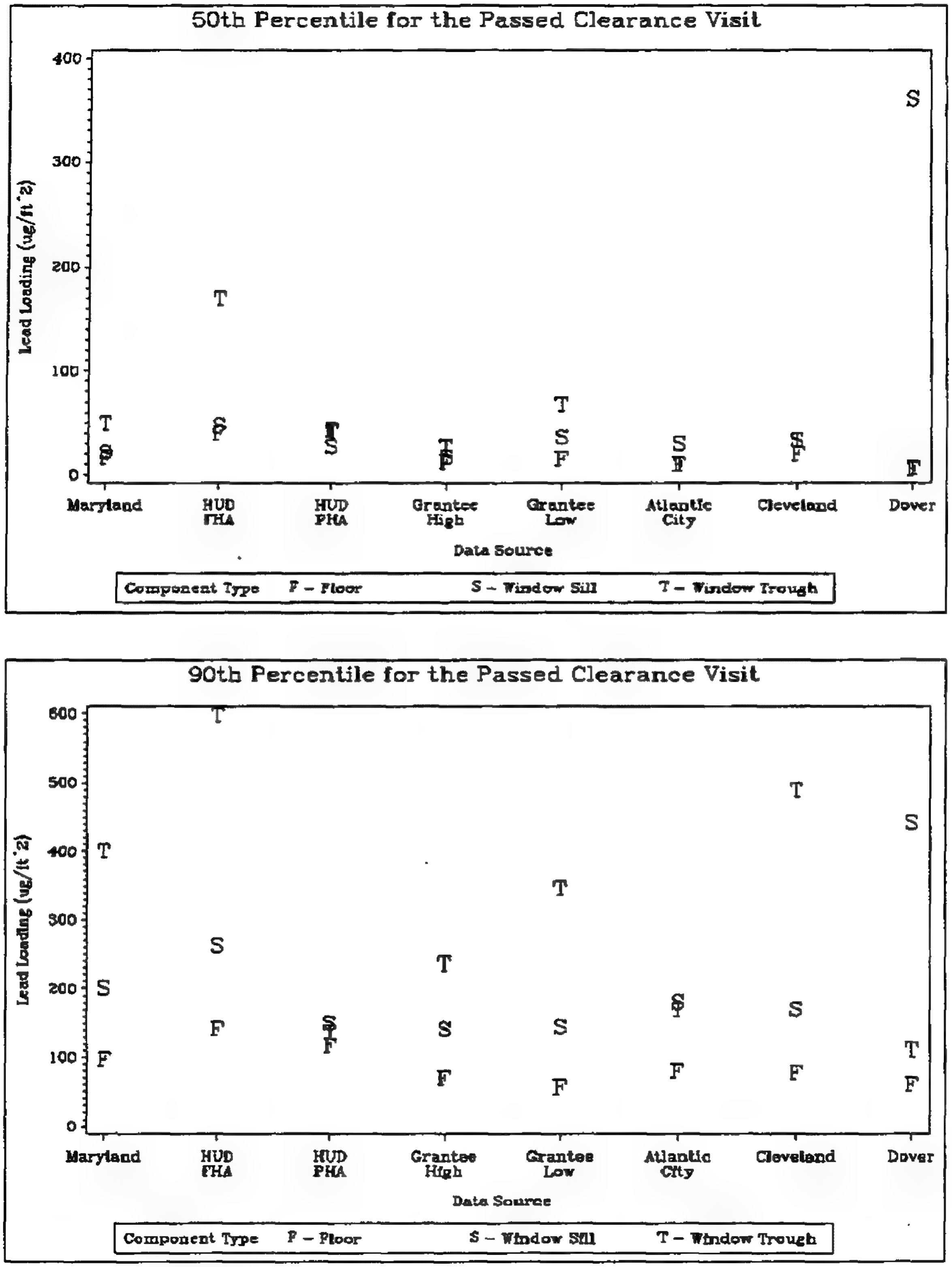


Figure ES-2. The 50th and 90th Percentiles for the Passed Clearance Visit, by Data Source and Component Type

1.0 INTRODUCTION

1.1 BACKGROUND

One method of lowering the risk of childhood lead poisoning is to perform environmental interventions which reduce or eliminate lead hazards (contaminated paint, dust, or soil) from the environment of a child's primary residence. Abatement and interim controls are interventions that are used to control lead-based paint hazards in a child's environment. Some of these approaches may potentially create a lead hazard in one or more environmental media while reducing or eliminating the targeted hazard. For example, the removal of deteriorated lead-based paint will often generate lead contaminated dust. Therefore, it is important that a thorough survey of possible residual lead contamination in environmental media surrounding the work area be conducted following any intervention.

Clearance testing is a procedure that is used to ensure that residents and unprotected workers are not exposed to lead contaminated media following an environmental intervention. Clearance testing is generally completed in two phases: a visual inspection, followed by a detailed sampling and analysis of the dust lead levels surrounding each work area. The visual inspection is used to verify that the contracted work was completed as specified, and that there is no visible settled dust or debris present in the work area(s). Once a given work area passes the visual inspection, then samples of dust surrounding that work area are collected and analyzed for lead content. The decision to allow either reoccupancy or further work by unprotected contractors is determined by comparing the results of the sample analyses to specific clearance criteria.

A lead contractor's work is not complete until each work area tested by the clearance inspector complies with the appropriate clearance standards. A particular work area may fail to meet standards in either phase of the clearance testing process. If a work area fails visual inspection, then the lead contractor must finish the work as specified, which usually includes a thorough cleaning process. If a work area passes visual inspection, but fails to meet the appropriate clearance criteria by virtue of environmental sampling and analysis, then the contractor must repeat the cleaning process on all areas represented by the failed samples until the work area is clean enough to achieve the criteria.

Although most leaded dust and debris generated by intervention appear in the form of surface deposition in surrounding environmental media, it is not possible to determine the extent to which lead contamination in media near the work area is directly attributable to the intervention. For example, dust surrounding an interior paint abatement work area may have contained high levels of lead prior to intervention. Nevertheless, the lead contractor is still responsible for cleaning the entire work area until dust-lead levels meet appropriate clearance criteria.

The dust wipe clearance standards under which much of the work in this report was performed were 200 $\mu g/ft^2$ for bare floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. These standards originated in the State of Maryland and were adopted by HUD in 1990 for HUD's "Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing" [2]. HUD [3] and EPA [5] later established 1994/1995 interim lead clearance standards of 100 $\mu g/ft^2$ for bare floors; 500 $\mu g/ft^2$ for window sills; and 800 $\mu g/ft^2$ for window troughs. Among 14 grantees participating in the HUD Grantee Program, 9 grantees used the clearance standard for floors under the HUD Interim Guidelines (200 $\mu g/ft^2$), 4 grantees used the HUD and EPA 1995 floor clearance standard at 100 $\mu g/ft^2$, and 1 grantee used 80 $\mu g/ft^2$ as the clearance standard for floors. In January 2001, under TSCA Title IV Section 403, the EPA issued the final dust-lead clearance standards of 40, 250 and 400 $\mu g/ft^2$ for floors, interior window sills, and window troughs, respectively [1]. The results presented in this report, however, were not based on these new final clearance standards.

1.2 OBJECTIVES

A thorough search for data sets that had field lead clearance dust wipe test results revealed the following potential data sources: the federally-funded FHA Lead-Based Paint Abatement Demonstration, the PHA Lead-Based Paint Abatement Demonstration, and the HUD Lead-Based Paint Hazard Control Grant Program; and data from four state or city programs: Maryland Department of Environment; Atlantic City, New Jersey; Cleveland, Ohio; and Dover, New Hampshire. Data were collected from all of these data sources (Table 1-1). The purpose of this document is to investigate the clearance data from these sources.

The clearance testing results correspond to measures of interior residential dust-lead loading from bare floors, window sills, and window troughs, and are reported in units of

micrograms of lead per square foot sampled (μg/ft²). Four objectives were pursued in the statistical analysis of the clearance sampling dust-lead loading results. They are as follows:

Table 1-1. Summary of Lead Clearance Data Sources.

Data Source	Locations	Period of Sample Collection	Type of Housing	Number of Dwelling Units	Average Number of Samples Per Unit
Maryland Department of the Environment	Baltimore City and Surrounding MD Counties	1991-95	Single Family Mostly Private	706	11
HUD FHA Demonstration Study	Baltimore/DC Birmingham, AL Denver, CO Indianapolis, IN Seattle/Tacoma, WA	1989-90	Single Family Private	149	19
HUD Demo Public Housing Authorities	Albany, NY Cambridge, MA Omaha, NE	1991-93	Multi-unit Public	119	12
HUD Lead Hazard Control Grant Program High Group*	9 Grantees across United States	1994-99	Single and Multi-unit Family	2150	8
HUD Lead Hazard Control Grant Program Low Group**	5 Grantees across United States	1994-99	Single and Multi-unit Family	1038	7
Atlantic City Housing Authority	Atlantic City, NJ	1994-95	Multi-unit Public	160	6
Cleveland Lead Hazard Abatement Center	Cleveland, OH	1993-95	Single Family Private	38	8
Dover Housing Authority	Dover, NH	1992	Multi-unit Public	158	6

* Grantees that used 200 $\mu g/ft^2$ as the clearance standard for floors.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as the clearance standard for floors.

Objective 1: Within each component type (and across component types), characterize the number of individual samples, work areas, and housing units that pass or fail clearance testing standards at various stages (i.e., site visits) of the clearance process.

Objective 2: Within each component type, characterize the distribution of dust-lead loadings, the geometric mean dust-lead loading, the variability between samples collected

from within the same housing unit, and the variability between samples collected from different housing units.

Objective 3: Characterize the correlation in dust-lead loadings between samples collected from different component types within the same work area.

Objective 4: Using lead-loading results from individual samples, demonstrate the impact that composite sampling would have on the pass/fail rate of houses by evaluating different types of clearance criteria placed on composite sample results.

To assess these objectives, analyses were performed for each data source individually. The analysis results from each of the data sources are summarized and discussed in the body of the report. Results for individual data sources are presented in the appendices.

1.3 DEFINITIONS

Throughout this document there are several special terms which will be used. For clarity, the definition of each term is given below.

HUD Interim Guidelines Clearance Standards

The clearance samples used in this report were, with one exception, collected in accordance with the 1990 HUD Interim Guidelines Clearance Standards [2]. The following is a brief description of what is included in the HUD Interim Guidelines Clearance Standards.

> The following steps were to be performed sequentially: a "preliminary" final clean-up effort, a preliminary final visual inspection to insure that all surfaces requiring abatement had been addressed and cleaned of all visible dust and debris, painting and sealing of abated surfaces and of floors, a final clean-up, and post-abatement visual inspection. Following the post-abatement visual inspection, dust wipe samples were to be collected and compared to clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window wells (now called window troughs). Results above the clearance standard required recleaning and retesting. The numerical values of 200, 500, and 800 $\mu g/ft^2$ are known as the HUD Interim Guidelines Clearance Standards.

These clearance standards, originating in the State of Maryland, were set at levels considered to be feasible and with the belief that these levels would reduce the number of children exposed after returning to a unit that had been abated.

The HUD Interim Guidelines Clearance Standards required a careful reading as to what action to take if a clearance sample was equal to the associated clearance standard. Since subsequent EPA guidance and regulation stated that equaling a clearance standard meant failing

clearance[3], this report interpreted "greater than or equal to" a clearance standard to mean that a sample failed clearance.

One exception to the procedures in the HUD Interim Guidelines Clearance Standards was the set of clearance samples collected in the HUD FHA Demonstration Project. This project used the National Institute of Building Sciences guidelines [6] that existed at the time of the study. In the FHA Demonstration, clearance testing was conducted after "final cleaning," but before the application of primers, recoatings, or sealants. The numerical clearance standards, however, were the same as in the HUD Interim Guidelines Clearance Standards.

Unless otherwise noted, the clearance standards used for the analyses in this report were the numerical standards in the HUD Interim Guidelines Clearance Standards.

Site Visit

After a housing unit had been abated and had passed a visual inspection the i^{th} site visit refers to the set of clearance dust wipe samples collected during that visit. For example, the first site visit would refer to the set of clearance samples collected right after the housing unit was abated, while the second site visit would typically include only those samples from components that failed clearance on the first site visit and required a second site visit to have samples collected.

Passed Clearance Data Set

This term refers to the dust lead clearance sample results collected within a housing unit that led to the housing unit passing clearance standards.

For example, consider a home where, during the first site visit, all floor and window sill dust wipe lead loading samples passed clearance, but two of the six window trough samples failed the clearance standard. As a result, the home failed clearance. After re-cleaning, during the second site visit two window trough samples were collected and they passed the clearance standard, thus passing the home. For this home, the Passed Clearance data set would then include all floor and window sill samples from the first site visit and the four window trough samples that passed clearance in the first site visit along with the two window trough samples from the second visit.

This data set was developed to assess component-specific distributions of lead in dust wipe samples that passed clearance testing from housing units that passed clearance. These distributions were used to address an important question: Given that a specific component type (floor, window sill or trough) passed the HUD Interim Guidelines Clearance Standards, what percentage of components would have also passed clearance if the standard would have been

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[3]EPA's rule on the clearance standards uses "equals or exceeds" as the failure criterion at 40 CFR 745.227(e)(8)(vii) [1] and "above or equal" as the failure criterion in the notice published at 60 FR 47248 [5].

lower, and the same level of stringency of cleaning and visual inspection were used? For example, what percentage of floor samples that had passed clearance testing at the 200 $\mu g/ft^2$ standard would have also passed clearance if the standard had been 100 $\mu g/ft^2$?

Component Type

Component type(s) in this document include: Interior Bare Floor, Window Sill, or Window Trough. Although there are other types of floor samples (e.g. carpeted floor samples), only bare floor samples were included in the analyses in this report.

Statistical Significance

Throughout this report geometric means are compared to determine if they are similar or statistically different. For two independent samples, the difference between the two geometric means is statistically significantly different if neither of the 95% confidence intervals contain the other (the level of significance is actually less than 5% for the comparison). All other statistical tests have a 5% level of significance.

HUD Grantee Data

This term refers to the Evaluation of the HUD Lead Hazard Control Grant Program data which were collected through January 1999 and were managed by the University of Cincinnati (UC) Department of Environmental Health. Fourteen grantees participated in the evaluation.

HUD Grantee (High) represents data from a group of nine grantees (Alameda County, Baltimore, Boston, California, Massachusetts, Milwaukee, Rhode Island, Vermont, and Wisconsin) that used the original HUD Interim Guidelines clearance standards, i.e., 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively. ***HUD Grantee (Low)*** represents data from the other group of five grantees (Cleveland, Chicago, New Jersey, New York City, and Minnesota) that used a lower floor dust-lead clearance standard (i.e. 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$).

Dust lead samples from HUD Grantee homes that received a no-action interior intervention strategy were not analyzed for the analysis in this report.

Work Area

The term "work area" refers to the room or room-equivalent (e.g., hallway, stairway) in which lead-hazard reduction activities had occurred within a residential unit.

1.4 STRUCTURE OF THE REPORT

For each objective listed above, Section 2 discusses the conclusions drawn from the statistical analyses. Section 3 lists the quality assurance information available from the data

sources. Background information specific to each study is presented in Section 4. Similar to Section 2, the statistical analyses used to assess the objectives are listed in Section 5 by objective. Section 6 presents the summary results of the analyses across all the data sources by objective. References are provided in Section 7. Appendices A through G present the results of the statistical analyses for each data source separately. Appendix H presents additional analysis results on the percentage of housing units that passed clearance on the first site visit, by the number of individual samples collected within a housing unit, Appendix I presents additional analysis results on the distributions of the clearance data, and Appendix J lists the key features of EPA and HUD clearance guidance and regulations that have been published from 1990 to the present.

1.5 PEER REVIEW

The report was peer reviewed on two separate occasions by individuals with expertise in the field. For the first peer review, five individuals were sent copies of the report and asked to provide comments. The following summary lists the major comments from the reviewers and responses to those comments. One of the reviewers recommended that clearance data from the HUD Grantee evaluation of interventions should be obtained, analyzed, and the results included in the report. This data was obtained, and the results of the analysis of this data were included in the revised report. Another reviewer commented that the types of housing covered in the report were largely from the Northeast region of the country and largely representative of government funded or subsidized housing. In particular, this reviewer felt government funded or subsidized housing would contain more homogeneous surfaces than would likely be encountered in most privately owned housing. The inclusion of the data from the HUD Grantee evaluation is responsive to both these concerns. Another reviewer commented on the difficulty of seeing similarities between individual source data and a combined set of all data from all sources. In response, the combined set of all data was not used in the analysis for the revised report.

Another reviewer commented on quality assurance aspects of data. Quality assurance information was reviewed. For one data source, clarifying information regarding the data could not be obtained, and all the data from that source was deleted in the revised report. For another data source, necessary clarifying information was identified and obtained. The report was updated and revised where necessary. One reviewer noted that there were errors in certain

formulas. Appropriate corrections were made to the report. A reviewer commented on the chemical analysis of composite samples. The composite samples in this report were created mathematically from single samples for statistical analysis. Text was revised to make it clear that the composite samples discussed in the report were constructed by mathematical combinations. A comment was received stating that there should be a literature search for the report. However, the report already contained in an appendix a summary of pertinent guidance and regulations regarding key features of clearance testing, and this summary of guidance and regulations was regarded as appropriate for the scope of the report.

In addition, there were numerous comments related to conclusions, presentation of data, and clarity of exposition. Graphical presentations of data were added, conclusions restated, and text revised in response to these comments.

Because the inclusion of the HUD Grantee data and the deletion of the combined data set across all sources were major changes to the report, a second peer review of the revised report was conducted. Four experts in the field, one of whom was in the original group of reviewers, were asked to peer review the report.

There were far fewer comments in this peer review compared to the initial peer review. The following summary is illustrative of the comments received in this peer review. One reviewer commented that the report should note the changes in clearance standards that would result from EPA's publication of a new rule on dangerous levels of lead. The report was updated to make the reader aware of these changes. (The data in the report itself were from clearance evaluations conducted before the publication of the new EPA rule.) A reviewer commented that statistical significance of results was not addressed in the discussion of the relationship between sample size and the probability of failing clearance at a house. Tables and text were revised to make the cases of statistically significant results clear to the reader. A comment was received regarding the use of the kappa statistic to adjust for expected chance concordance. Upon review, a determination was made that the analysis of conditional probabilities among the types of components typically tested addressed the information need expressed by the reviewer, and accordingly the kappa statistic was not used.

EPA has established a public record for the peer review of this report under Administrative Record 235. The administrative record is available in the TSCA Nonconfidential Information Center, which is open from noon to 4 pm Monday through Friday, except legal

holidays. The TSCA Nonconfidential Information Center is located in Room NE-B607, Northeast Mall, 401 M Street SW, Washington D.C.

2.0 FINDINGS AND CONCLUSIONS

The data from eight data sources contain an extensive amount of dust-lead loading clearance testing results for single and multi-family dwelling units. The data represent the amount of lead left behind following lead-based paint abatement or other interventions once attempts have been made by lead contractors to meet the HUD Interim Guidelines Clearance Standards. Four objectives were addressed in the statistical analysis of the clearance sampling dust-lead loading results and were described in Section 1. In this section, an assessment of each objective is presented. Later, in Section 5, details of the statistical analysis procedures used to assess each of the objectives are presented.

For the HUD Grantee data, two analyses were performed: one for a group of nine grantees that used the HUD Interim Guidelines clearance standards (i.e., 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively); the other for a group of five grantees that used a lower floor dust-lead clearance standard. The first group includes Alameda County, Baltimore, Boston, California, Massachusetts, Milwaukee, Rhode Island, Vermont, and Wisconsin. The second group includes Cleveland, Chicago, New Jersey, and New York City, which use 100 $\mu g/ft^2$ as the floor dust-lead clearance standard, and Minnesota, which uses 80 $\mu g/ft^2$. The first group is labeled as "HUD Grantee (High)" and the second group is labeled as "HUD Grantee (Low)" in this report.

Each individual data source was analyzed separately. The results of these independent analyses of each data source are located in Appendices A through G. The analysis results from each of the data sources are summarized and discussed in the main body of this report. Altogether there are eight data groups presented in this report, i.e., data from Maryland, HUD FHA, HUD PHA, HUD Grantee (High), HUD Grantee (Low), Atlantic City, Cleveland, and Dover.

2.1 OBJECTIVE 1: CHARACTERIZATION OF THE NUMBER OF INDIVIDUAL SAMPLES, WORK AREAS, AND HOUSING UNITS THAT PASS OR FAIL CLEARANCE TESTING STANDARDS

- On average there were 8.0 dust wipe samples taken per housing unit on the first site visit. Failure rates of individual samples, averaged across eight data sources, were lowest for floor samples at 8.7% (the range, over the eight data sources, is from 2.1% to 18.8%) followed by samples from window troughs at 10.4% (ranges from 1.9% to

36.4% over eight data sources) and samples from window sills at 10.5% (ranges from 1.1% to 38.9% over eight data sources) during the first site visit. The proportion of housing units that failed clearance testing during the first site visit was higher, with an average of 16.8% of units failing based on high window trough dust lead levels (ranges from 3.4% to 56.5% over eight data sources), 23.0% failing clearance based on high floor dust lead levels (ranges from 7.3% to 46.2% over eight data sources), and 18.5% failing clearance based on high window sill dust lead levels (ranges from 3.0% to 41.7% over eight data sources). The higher failure percentages associated with housing units is due to that fact that a housing unit fails clearance if any individual dust wipe sample from a given component fails clearance, and in fact many of the units that failed clearance testing had high lead levels on more than one component type.

- Based on a logistic regression model of first site visit data, the estimated probability of failing clearance testing increases with the number of dust samples collected. For example, among 4,487 residential units, it was estimated that approximately 25.4% failed clearance when 2 samples were collected, 27.3% failed when 4 samples were collected, and 28.9% failed when 6 samples were collected. This trend may be attributable to more intensive sampling being conducted in residential units that either required more lead hazard control work, or that were in poor condition.

- On the first site visit, an average of 91.8% of the individual dust wipe sample results and 88.1% of the rooms tested passed the HUD Interim Guidelines Clearance Standards, while only 66.9% of the housing units passed clearance. Eventually, 87% of the housing units were known to have passed. The remaining 13% of the units that did not pass clearance testing mostly were considered losses to follow-up, attributed to families moving, litigation, poor record keeping, housing units that were still in the process of meeting clearance, or housing units that never passed clearance testing; however, some of these probably eventually passed clearance. Since 87% of the housing units passed clearance and only 13% of the housing units were lost to follow-up or some might simply have failed clearance after multiple attempts, a conclusion was drawn that the clear majority of residential housing units could pass clearance if properly abated and allowances are made for multiple clearance testing site visits.

2.2 OBJECTIVE 2: CHARACTERIZATION OF THE DISTRIBUTION OF THE DUST-LEAD LOADINGS, GEOMETRIC MEAN DUST-LEAD LOADINGS, VARIABILITY WITHIN A HOUSING UNIT, AND VARIABILITY BETWEEN HOUSING UNITS

- For each of the first two site visits, the geometric mean dust wipe lead loading from floors was significantly lower than the geometric mean for window sills. In turn, the geometric mean of window sill samples was significantly lower than the geometric mean of the window trough samples in the first two site visits. This trend of geometric mean floor dust-lead loadings being lower than window sill dust lead loadings, and window sills being lower than window troughs continued in the third

and fourth site visits; however the differences in these later site visits were not generally statistically significant due to smaller sample sizes. These results suggest that window sills generally could not be cleaned to the same levels as floors, and window troughs could not be cleaned to the same levels as window sills. However, these results do indicate that current lead clearance standards can be reasonably attained by lead abatement contractors.

- The geometric mean lead loading of the samples collected for each component type generally increased from the first site visit to the third site visit. For example, the geometric mean floor dust lead loading from samples collected during the first site visit ranged from 8.8 to 57.6 $\mu g/ft^2$ with an average of 27.0 $\mu g/ft^2$, from 13.8 to 99.9 $\mu g/ft^2$ with an average of 40.2 $\mu g/ft^2$ during the second site visit, and from 19.7 to 213.4 $\mu g/ft^2$ with an average of 77.0 $\mu g/ft^2$ during the third site visit. This trend is expected since generally only homes that failed clearance testing were resampled in the subsequent site visits. Samples that were taken in the later site visits would be expected to have higher lead loadings because only the "dirtiest" homes would be included.

2.3 OBJECTIVE 3: CHARACTERIZATION OF THE CORRELATION BETWEEN COMPONENTS SAMPLED IN THE SAME WORK AREA

- In each of the first three site visits, within room correlation coefficients were estimated among dust-lead loadings from floors, window sills, and window troughs. In each of these site visits, the highest correlation was observed between window trough and window sill samples, followed by the correlation between floors and window sills, with the lowest correlation being observed between floors and window troughs.

- If a dust-lead loading of one component type is below the HUD Interim Guidelines Clearance Standard, it is very likely that the dust-lead loading for another component type within the same room will be below its respective clearance standard. For example, as seen in Table 6-12a, given that the window sill dust-lead loading is less than 500 $\mu g/ft^2$, there is a high probability (> 84%) that a floor dust-lead loading sample collected from within the same room will be less than 200 $\mu g/ft^2$.

- The probability that a component will fail its HUD Interim Guidelines Clearance Standard given that a different component from the same room failed its respective clearance standard is generally below 50% (Tables 6-12a to 6-12c). A notable exception is that when a window sill sample fails clearance, the probability that the window trough sample will also fail is greater than 72% for some data sources and still less than 30% for some other data sources (Table 6-12c).

2.4 OBJECTIVE 4: DEMONSTRATION OF THE IMPACT OF COMPOSITE SAMPLING ON PASS/FAIL RATES OF HOUSES

- When comparing lead loading results to the HUD Interim Guidelines Clearance Standards, it is very plausible that different clearance decisions (Pass/Fail) will be

made based on the use of either individual samples or composite samples. For example, of the 2,092 homes in the HUD Grantee High data group, 1,872 homes would have passed clearance for floor dust based on simulated composite samples. Of the 1,872 homes, only 1,775 homes would have passed floor dust clearance if individual samples were considered (97 homes would have failed) (Table 6-14).

- The results of the analysis of simulated composite samples indicated that composite sampling is associated with an decrease of sensitivity when using the HUD Interim Guidelines Clearance Standard. (Sensitivity is the probability of a composite sample failing clearance when at least one of the subsamples within that composite had a lead-loading result above or equal to the HUD Interim Guidelines Clearance Standard for individual samples. Higher sensitivity indicates a better possibility of making correct failing clearance decisions based on the composite samples.) For example, the probability ranges from 18.2% to 62.7% that a dwelling will fail clearance based on simulated floor composites where at least one of the individual samples in the composite is above or equal to the floor clearance standard. The probability ranges from 25% to 100% that this will happen for window sills and ranges from 20% to 100% for window troughs. Most of the sensitivities are at or below 80% for three component types and across eight data sources.

- Comparison of composite sample lead-loading results to standards which are lower than the HUD Interim Guidelines Clearance Standard for each component type resulted in an increase in sensitivity. Two such composite clearance criteria were defined and compared. The 2×Standard/n criterion resulted in fewer false clearance passes than the HUD Interim Guidelines Clearance Standard, and fewer false clearance failures than the Standard/n criterion.[4] (The definitions of the criteria are provided in Section 5.)

- The clearance testing results can be summarized with performance characteristics for each combination of component type and composite clearance criteria which are defined in terms of sensitivity, specificity, positive predictive value, and negative predictive value. (The definitions of performance characteristics are provided in Section 5.) Reducing the standard by using the 2×Standard/n criterion provided the best performance across all of the performance characteristics.

[4]Refer to 40 CFR Part 745.227(e)(8)(vii) for the EPA regulation published in January 2001 regarding the interpretation of composite sample results for clearance testing and to the Federal Register, Volume 66, No. 4, January 5, 2001, page 1223 for the basis for the regulation.

3.0 OVERALL QUALITY ASSURANCE

Lead dust clearance data were obtained from three federally funded projects: the HUD FHA and PHA Lead-Based Paint Abatement Demonstration Projects and HUD's Lead-Based Paint Hazard Control Grant Program (HUD Grantee Program) and from four state or local programs: the Maryland Department of the Environment; the Atlantic City (New Jersey) Housing Authority; the Dover (New Hampshire) Housing Authority; and the Cleveland (Ohio) Lead-Hazard Abatement Center.

The data represented clearance results corresponding to specific abatement or lead hazard reduction interventions that took place between 1989 and 1999. Clearance activities in the HUD FHA study followed the procedures in the NIBS Guidelines [6]. Clearance activities in the other studies or projects generally followed the procedures in the HUD Interim Guidelines [2]. The data collected included 39,301 lead-loading clearance dust wipe sample measurements on floors, window sills, and window troughs from 4,518 dwelling units.

The public housing authorities, city agency, and state agency all indicated that they followed the recommendations in the HUD Interim Guidelines [2] to have clearance samples analyzed by laboratories that had appropriate credentials. The recommendations in the HUD Interim Guidelines and associated list of laboratories for lead analysis were developed by EPA for HUD. The recommended laboratories in the Interim Guidelines were accredited by the American Industrial Hygiene Association, or the American Association for Laboratory Accreditation, or the EPA Contract Laboratory Program. The HUD FHA and PHA Demonstrations were conducted with oversight by HUD. The grantees in the HUD Grantee program were required to submit samples to laboratories that had passed the proficiency testing of the Environmental Lead Proficiency Analytical Testing (ELPAT) program [7]. (This program later became part of the EPA National Lead Laboratory Accreditation Program (NLLAP) [8], which was the successor to the list of laboratories recommended in the HUD Interim Guidelines.) Hence all studies and programs which provided data for this analysis are regarded as having followed adequate procedures and laboratory analysis for the purposes of dust clearance testing.

Some of the data submitted were associated with a published study or had undergone extensive quality assurance checks. Other data were submitted on hard copy forms and had to be key entered. A quality assurance/quality control program was developed for this study to handle

each set of data in a way commensurate with its status and to establish consistency across sets of data. The following steps were taken as part of the quality assurance/quality control program:

- Data Entry Using Paradox Interface - Data received in hard-copy format were entered into a database via a Paradox interface. Important alphanumeric characterization variables were checked against the look-up tables to ensure accuracy of entry.

- Data-Checking Programs - Programs were written to screen the data for obvious errors and systematic coding mistakes. These programs included a series of range checks, frequency counts, and scatterplots that were reviewed by the Quality Assurance Team.

- Outlier Analysis - An outlier analysis was performed to determine if any of the lead loading measurements fell significantly outside the expected range of the clearance results.

- Data Audit - At least 5-10% of the data were subjected to a data audit. Data values taken from the study database were hand-checked against the original hard-copy or electronic data files. Of the data that were checked, less than 1% was found to be problematic. The records in question were identified in the database, located in hard copy reports, and corrected or verified.

After resolution of all issues and records in question identified in the steps above, the statistical analysis proceeded. Results of statistical analyses were double checked and revised as necessary. Software was written to reduce transcription errors from the results of analysis programs to the tables in the report. The report was reviewed extensively for accuracy and consistency. Finally, two peer reviews were conducted to ensure that conclusions and methodology were sound.

4.0 DESIGN, DATA COLLECTION, AND CHEMICAL ANALYSIS

Below is a summary of available background information for each data source. When possible, information is included in the descriptions pertaining to incidence and levels of lead-based paint in the houses, age of units, the abatements or interventions that were performed, circumstances of cleaning, use of sealants, and clearance testing specifics. The FHA and PHA federally funded housing projects have extensive details that are part of published reports [9-12]. The summary of available background information for the HUD Grantee data is based on the Fifth Interim Report of the evaluation of the HUD Grantee Program [13]. Information on the housing units collected from the state and local housing authorities is not as detailed. Because much of the data collection was performed several years ago and/or the original data collectors could not be contacted, some background information was not available.

4.1 FHA SINGLE-FAMILY HOUSING PHASE OF THE HUD ABATEMENT DEMONSTRATION PROJECT

The HUD Abatement Demonstration Project was conducted from 1989 - 1990 to assess the costs and benefits associated with several lead-based paint abatement methods [14]. In the FHA single-family housing phase, the demonstration was conducted in HUD-owned vacant single-family dwelling units [9]. The FHA held title to the houses. A total of 304 units from several different U.S. cities were screened for leaded paint, and 172 units were found with sufficient amounts of lead-based paint to warrant abatement. Paint abatement methods performed during the FHA phase included enclosure, encapsulation, chemical removal, removal with heat gun, removal and replacement, and abrasive removal.

Following abatement, clearance testing was conducted using individual wipe samples in 149 units. Note that three of the 172 units were used as pilot units and 20 units had only exterior abatement. Wipe dust-lead loading results from all clearance samples were available in the HUD Demonstration Lead-Based Paint (HUDLBP) Database [15]. Clearance dust-wipe samples were collected after the unit had been "final cleaned," but prior to recoating or priming of any surfaces. Housing units passed clearance testing if all surfaces sampled resulted in dust-lead loadings below the HUD Interim Guidelines Clearance Standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. If these dust lead standards were not met, the study protocol required the housing unit to undergo more extensive cleaning and repeated

clearance wipe sampling until the unit met the standards, for up to three iterations of cleaning and retesting. However, data from the HUDLBP Database indicated that several units underwent more than three clearance testing iterations. Additional information on the HUD Demonstration Lead-Based Paint Database can be found in [15].

4.2 PUBLIC HOUSING ADMINISTRATION (PHA) PHASE OF THE HUD ABATEMENT DEMONSTRATION PROJECT (ALBANY, OMAHA, CAMBRIDGE)

The three PHAs selected to participate in the HUD Demonstration were Albany, New York; Omaha, Nebraska; and Cambridge, Massachusetts [14]. A total of 109 units were included at these three demonstration sites. The following material is comprised of excerpts from published reports [10-12].

The PHA Phase of the HUD Abatement Demonstration Project was performed to assess the costs and benefits associated with performing lead-based paint abatement in multifamily housing. The project in Cambridge involved two garden apartment buildings, each with 24 housing units. Paint abatement was conducted using chemical methods for the housing units in one building, and abrasive methods were used for the housing units in the other building. In Albany, there were also two apartment buildings, each with 18 housing units. Paint abatement was performed in the first building using encapsulation and enclosure systems, and chemical stripping was used for housing units in the second apartment building. The apartment complex in Omaha consisted of brick faced townhouses, which were abated using component removal and replacement.

Following abatement, clearance testing using individual wipe samples was conducted in the housing units of each building. Wipe dust-lead loading results from all lead clearance samples were available from records collected during the study. Housing units passed clearance testing if all surfaces sampled resulted in dust-lead loadings below the HUD Interim Guidelines Clearance Standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. If these dust lead standards were not met, the study protocol required the housing unit to undergo more extensive cleaning and repeated clearance wipe sampling until the unit met the standards. All units abated passed clearance.

4.2.1 The Albany Demonstration

The project in Albany involved a major redesign of two 18-unit, three-story buildings which are part of a 6-building, 108-unit project. Because the Albany Housing Authority (AHA) chose to carry out almost complete redesign of the buildings, many building components were removed and replaced.

Background

The Robert Whalen Homes Development, Albany's first public housing project, was constructed in 1950, and consisted of six similar three-story buildings, each with six units per floor, or eighteen units per building. Four of the buildings (Buildings A-D) are in a cluster. The buildings are brick with concrete slab floors, steel frame windows, and wood interior doors, shelves and trim. There was a single entry and central stairway in each building. Interior hallways provided access to the individual units. The demonstration was carried out in only two buildings.

All six of the Robert Whalen Homes buildings were deleaded and modernized. The rehabilitation of the demonstration buildings called for the central boilers to be replaced with modular boilers in each building. The electrical service system was to be replaced. Vinyl tile flooring was to be installed over existing vinyl asbestos tiles and asbestos-containing pipe insulation was removed throughout the building. The fire alarm system was replaced, a new sprinkler system was installed, and all doors were replaced. Kitchen cabinets and sinks, and bathroom fixtures and toilet accessories that were installed during the previous modernization were saved and re-used.

The buildings were also redesigned so that ground floor units would have their own outside entry. The second and third floors were used to create two-story units.

The Extent of Lead-Based Paint in the Demonstration Buildings

The demonstration buildings were tested for lead-based paint over the period March - April 1990. The XRF testing was performed according to the HUD Interim Guidelines using Warrington Microlead I Revision 4 portable XRF analyzers. Paint samples were obtained from all substrates for atomic absorption spectroscopy (AAS) testing, whether or not the XRF results indicated a need for confirmatory AAS testing. Because the buildings were occupied during the

testing, the area where paint samples were obtained was immediately resealed. The XRF and AAS test results were similar in both buildings.

Lead-based paint, as measured by XRF analyzers, was mostly limited to closet shelves and shelf supports, bathroom doors, limited areas of walls and ceilings, window sills, and stair treads and risers on the interior steel common staircases. The XRF results indicated a high percentage of window sills (76%) and risers (64%) contained lead-based paint, but this finding was in conflict with laboratory AAS test results (2% and 0%, respectively), which are considered to be more precise and accurate. "This difference probably reflects the measurement error associated with XRF testing, particularly on metal surfaces. In all cases in which the XRF and AAS findings differed substantially, the XRF results indicated a higher incidence of lead-based paint hazards" [11].

A total of 3,034 XRF readings were obtained and 12% were above or equal to the threshold of 1.0 mg/cm². In addition, 1,226 AAS samples were obtained and 4% were above or equal to the threshold of 1.0 mg/cm².

4.2.2 The Omaha Demonstration

The Omaha Demonstration buildings are two-story town house structures constructed in 1938. The six buildings contain a total of 49 units ranging in size from 1 to 5 bedrooms. Construction is concrete frame floors with brick on the exterior walls, and partition walls are plaster over clay tile. Interior stairs are metal with concrete treads. During the course of previous modernization work, all windows and window frames had been replaced, and new soffits, fascias, and porches had also been installed. Doors, door frames, window sills, shelves, shelf-cleats, and baseboards were painted wood.

The Stage IV modernization plans for the Southside Terrace buildings consisted of seven types of improvement: (1) enclosing or removing asbestos tile floors and removing asbestos in crawl spaces and basements, (2) insulating and furring interior and exterior walls and covering interior walls with new sheetrock, (3) reconfiguring the upstairs of most units to change the number of bedrooms, moving partitions in the washer/dryer, kitchen, and pantry areas, and eliminating exterior storage sheds, (4) replacing plumbing and plumbing fixtures in bathrooms, (5) installing new ceilings and new overhead lighting, (6) replacing existing cabinets, installing

new closets, and improving access to under-stair storage area, and (7) replacing existing hot water heating system with electric radiant heat.

The painted surfaces in these units consisted of baseboards, window sills, interior doors and door frames, exterior doors and door frames, shelves, shelf-cleats/chair rails, interior walls and ceilings. Planned modernization of these units would have effectively abated most of the lead-based paint even without the lead abatement objective.

The Extent of Lead-Based Paint in Demonstration Buildings

Systematic testing of the six Demonstration buildings for the presence of lead-based paint was performed using protocols described in the Research Design. The first four buildings (the Group 1 buildings) were tested using Warrington Microlead I Revision 4 portable XRF analyzers. Paint samples were taken from substrates which could not be tested with the XRF machines and subjected to laboratory analysis using atomic absorption spectroscopy (AAS). AAS tests were also performed, when XRF readings were in the range where confirmatory AAS testing was required by the HUD Interim Guidelines, and when confirmatory testing was required by the Research Design for the Demonstration. The two buildings added later (the Group 2 buildings) were tested for lead-based paint in the same way, except that the portable XRF analyzer used was a Scitec instrument. Testing in all buildings was carried out after the units had been vacated. The Douglas County standard of 0.6 mg/cm^2 and the HUD Interim Guidelines standard of 1.0 mg/cm^2 of lead were used as criteria for classifying a reading as positive. There were 2,190 XRF readings from Building Group 1 and 1,522 from Building Group 2.

The use of the more stringent 0.6 mg/cm^2 standard (compared to the 1.0 mg/cm^2) for abatement increased the percentage of all building components testing positive on the XRF reading from 8% to 17% in Building Group 1 and from 34% to 43% in Building Group 2. The percentage of all building components testing positive on the AAS samples increased from 4% to 6% in Building Group 1 and from 21% to 27% in Building Group 2. For some components, the percentage testing positive was almost the same under both standards (i.e., baseboards, shelf-cleats, doors, and door frames on the XRF readings and door frames and window sills on the AAS test), while for others, the difference in the percentage testing positive was quite striking (i.e., ceilings and walls on the XRF readings and ceilings on the AAS test).

4.2.3 The Cambridge Housing Authority Demonstration

The CHA's Newtowne Court project contains 282 units, configured into a number of three story walk-up buildings. The project was constructed in 1938. The building construction consists of brick exteriors, load bearing 4" block interior walls covered with plaster, and concrete floor slabs. Each building also has a full basement, with some being used for storage and laundry facilities.

The condition and layout of the units in Newtowne Court was consistent with public housing units built in the late 1930s – deteriorated interior surfaces, small and inefficient kitchens, outdated baths, and numerous coats of paint, applied both by the CHA and tenants. CHA's initial modernization plans included the construction of a bay window, or extension, in the kitchen to provide needed additional space. CHA also planned on modernizing the bathrooms and restoring the remainder of the units to present-day standards. Extensive site improvements were also planned. A new heating system had been installed in 1985; however the buildings' plumbing and electrical systems required a full upgrade. All asbestos-containing pipe insulation was to be removed during the modernization.

CHA's strategy for modernization involved vacating two 12-unit buildings, completing modernization in these buildings, and then using the completed buildings as a temporary "hotel" for the residents, until their buildings were modernized. These two initial buildings were selected for the demonstration. Each building has two central stairways, each having access to two units on each of the three floors.

The Extent of Lead-Based Paint in the Demonstration Buildings

The two demonstration buildings were tested for the presence of lead-based paint during the spring of 1990. The XRF testing protocols were the same as those in the HUD Interim Guidelines except that five repeated measurements per test point were taken using a Warrington Microlead I ML-1, Revision 4 direct reading XRF machine, versus three measurements specified in the HUD Interim Guidelines[5]. Comprehensive AAS sampling was also performed whether or not the XRF results indicated a need for confirmatory AAS testing. Confirmatory testing

[5] Massachusetts regulations required that the average of 5 repeated measurements taken at the same point be used to determine the need for abatement.

involves the extraction of paint chip samples on substrates where the XRF readings were within a defined range around the abatement threshold of 1.0 mg/cm². This process is detailed in the report [10], and was done to permit comparisons of XRF and AAS measurements on a wide range of lead paint concentration levels. The only other variance from the HUD Interim Guideline protocols was CHA's decision to test both sides of each door frame by AAS because different sides of the door frames may have had different paint histories.

A total of 2,194 XRF readings were obtained; 16% indicated lead levels above or equal to the 1.0 mg/cm² threshold. In addition, 896 AAS samples were obtained and 11% were above or equal to the 1.0 mg/cm² threshold.

4.3 MARYLAND DEPARTMENT OF THE ENVIRONMENT

The Lead Enforcement Group within the Maryland Department of the Environment (MDE) has been actively conducting post abatement clearance testing since 1988 [16]. When they first started their clearance testing program, there were no protocols for sampling or standards developed for the purpose of clearance testing. Based on scientific evidence, this program developed protocols for the collection of dust wipe samples from floors, window sills, and window troughs in rooms that had received abatement. The clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs also originated from within the MDE Lead Programs. These standards were based on pilot data, and were designed so that a work area would pass clearance through reasonable cleaning efforts on the part of the lead contractor. These clearance standards also represented levels of post-abatement lead on floors, sills and troughs that were far below the levels of lead that would typically be observed on these components prior to abatement.

The lead enforcement group has archived data on dust-lead loading results since they started conducting clearance sampling in 1988. These data existed only in hard copy form, and were made available to EPA for the purposes of this project. All clearance testing sample results collected between January 1, 1991 and January 30, 1995 were entered into an electronic database for the purposes of this investigation. The statistical analysis of data from MDE represents these four years of clearance testing results throughout the state of Maryland.

If the results from a dust-lead loading sample exceeded the clearance standards, the area had to be recleaned and retested until acceptable results were obtained for each unit. However,

there are no records of additional testing for approximately 23% of the units which failed clearance. These losses to follow-up may be attributed to families moving, litigation, or poor record keeping. Some of these may have been houses that had ongoing recleaning and retesting after January 1995. Since the Lead Enforcement Group within MDE is a state regulatory program, and not a research program, this loss to follow-up within the data could not be avoided.

4.4 EVALUATION OF THE HUD LEAD-BASED PAINT HAZARD CONTROL GRANT PROGRAM

The following summary is based on the "Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program: Fifth Interim Report, Progress as of September 1, 1997," which was published in March 1998 [13].

The overall purpose of the evaluation of the HUD Lead-Based Paint Hazard Control Grant Program ("HUD Grantee Program") is to measure the relative cost and effectiveness of the various methods used by State and local government grantees to reduce lead-based paint hazards in housing [17]. Approximately 2,900 dwelling units were followed for 12 months and approximately 750 units were followed for 36 months [13]. Although national in scope, this program is locally driven and implemented. Grantees design their own programs, including the methods of recruitment and the treatments that they carry out.

There are 14 grantees in the HUD Grantee Program, with 11 starting in FY 1992 (first round, required to participate) and 3 starting in FY 1993 (second round, voluntary participation). The administration, sampling targets, and abatement methods that were used by each grantee are summarized in Table D-1. Program standard forms and procedures were developed by the University of Cincinnati (UC) Department of Environmental Health and the National Center for Lead-Safe Housing (NCLSH). UC and NCLSH are also responsible for data analysis and reporting, training, and support of grantee data collection and recording. Data management quality control was done by UC.

Data being collected in the HUD Grantee Program are environmental, biological, demographic, housing, cost, and hazard-control information. Measurements of lead in dust, paint, soil, and blood are collected, though not all grantees collect all these measurements. Pre-intervention, immediate post-intervention (clearance results), and 6- and 12-month

post-intervention data are collected. However, only selected homes (estimated 800 homes) are included in the data collection for the 24- and 36-month post-interventions.

This report analyzes the latest set of HUD Grantee data, which was collected through January 1999 and was released by the University of Cincinnati in June 1999.

Based on the HUD Grantee Program's Fifth Interim Report [13] (data collected through September 1, 1997), the following provides basic information on building characteristics, occupancy status, environmental sampling, and clearance of the dwelling units in the program.

Building Characteristics

(1) Types

- Single family detached (32%)
- Single family attached (25%), rowhouses - mostly in Baltimore
- 2-4 Unit Multi-family (37%)
- > 4 Unit Multi-family (6%), 85% of NY enrollments were of this type, averaging 14 units per building

(2) Age of Housing

- Less than 1% of the enrolled buildings built after 1959
- 90% pre-1940
- Median for Cleveland, Massachusetts, Milwaukee, Minnesota and Vermont is pre-1910
- Median for Baltimore, Chicago and Rhode Island was in 1920's
- Median for California was in 1930's

Occupancy Status

- 20% vacant prior to intervention
- Baltimore had 60% pre-intervention vacancy rate
- Vermont, NY, NJ had from 24% to 34% pre-intervention vacancy rates
- All others had below 14% pre-intervention vacancy rate

Environmental Sampling

- Dust is collected from 7-9 locations during each phase of the evaluation.
- Single-surface dust wipe samples are collected from:
  - Floor (bare or carpeted): interior entry, kitchen, child's play room (or living room), youngest child's bedroom (or smallest room), next youngest child's bedroom (if present). Note that only bare floor dust samples were included in the analyses in this report.
  - Interior window sill: kitchen, youngest child's bedroom (or smallest room)

- Window trough: child's play room (or living room), next youngest child's bedroom (if present)

Clearance of the Dwelling Units

- Program requires clearance after intervention
- Clearance standards follow 1990 HUD Interim Guidelines
  Floors: 200 $\mu g/ft^2$
  Sills: 500 $\mu g/ft^2$
  Troughs: 800 $\mu g/ft^2$
- Since 1994-1995, grantees have been allowed to use 200 $\mu g/ft^2$, 100 $\mu g/ft^2$ or use a locally established level as the clearance level for floors. Five grantees chose to use lower clearance levels for floors.
  - Cleveland, Chicago, New Jersey, New York City used 100 $\mu g/ft^2$
  - Minnesota used 80 $\mu g/ft^2$
- 28% of the dwelling units failed the initial clearance dust lead test. There is a wide variation in the clearance rates for the grantees, with rates of initial failure ranging from 8 to 50% [13].

All dwellings in the HUD Grantee program are required to "meet clearance" after the intervention is complete. In other words, dust wipe tests must demonstrate that the amount of leaded dust on components in all treated rooms does not exceed levels designated by HUD. For the first and second rounds of the HUD Grantee Program, clearance levels were set at 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively. In 1994-1995, HUD and EPA released new guidance that lowered the clearance level on floors, from 200 $\mu g/ft^2$ to 100 $\mu g/ft^2$. Since then, HUD has allowed grantees to use either 200 $\mu g/ft^2$, 100 $\mu g/ft^2$, or a locally established level if less than 200 $\mu g/ft^2$. Five grantees used clearance levels less than 200 $\mu g/ft^2$ for floors: Cleveland, Chicago, New Jersey, and New York City used 100 $\mu g/ft^2$, while Minnesota used 80 $\mu g/ft^2$.

A main attribute of the HUD Grantee program is the flexibility that grantees have to select the lead treatments for any particular unit. The grantees have the freedom to treat all areas of the property or treat only some locations (interior, exterior, and/or soil). The grantees also decide on the intensity of the treatment. Possible treatment intensities range from cleaning with some spot painting to partial abatement to full abatement. The grantees have been encouraged to experiment with different levels of lead hazard control activities. Grantees are allowed to experiment because there is no consensus on a single state-of-the-art intervention to control lead-based paint hazards. For example, some grantee programs require that windows containing

lead-based paint be replaced to protect the health of residents. Others contend that by using lower level/lower cost treatments, more residents can be served, while still protecting their health. Grantees have even decided to leave some lead-based paint hazards untreated, under the assumption that these hazards have no or limited immediate impact on the residents' health.

Grantees report the intensity of the interior intervention as strategy code (level 01 to 07). Higher strategy levels reflect more intensive treatment. Each dwelling unit was assigned only one interior intervention strategy. The interior intervention strategies are summarized in Table 4-1. Grantees, as a whole, have selected a diversity of strategies. On an individual basis, however, most grantees have tended to select one or two dominant strategies [13].

Table 4-1. Interior Intervention Strategy Code Definitions

Level	Definition
1	No Action
2	Cleaning, Spot Paint Stabilization Only
3	Level 02 plus Complete Paint Stabilization, Floor Treatments
4	Level 03 plus Window Treatments
5	Level 04 plus Window Replacement, Wall Enclosure/Encapsulation
6	All Lead-Based Paint Enclosed, Encapsulated, or Removed (Meets Public Housing Abatement Standards)
7	All Lead-Based Paint Removed

Note: Dust lead samples from grantee houses that received a no action interior intervention strategy were not analyzed for the analysis in this report.

Glossary of HUD Grantees Interior Intervention Strategies:

Encapsulation - The application of a covering or coating that acts as a barrier between lead-based paint and the environment, the durability of which relies on adhesion and which has an expected life of at least 20 years.

Enclosure - The application of rigid, durable construction materials that are mechanically fastened to the substrate to act as a barrier between lead-based paint and the environment.

Paint Stabilization - The process of repainting surfaces coated with lead-based paint, that includes the proper removal of deteriorated paint and priming.

Paint Removal - The complete removal of lead-based paint by wet scraping, chemical stripping, or contained abrasives.

Removal/Replacement - The removal/replacement of a building component that was coated with lead-based paint.

Window Treatments - The process of eliminating lead-containing surfaces on windows that are subject to friction or impact through the removal of paint or enclosure or certain window components.

4.5 ATLANTIC CITY HOUSING AUTHORITY

The Atlantic City Housing Authority provided data from a comprehensive rehabilitation project performed on public housing buildings containing 10 to 23 multi-family housing units [18]. These two- to three-story brick buildings had lead-based paint on the doors, windows, radiators, trim, and stairwells. The Atlantic City Housing Authority removed the doors and windows and replaced them along with most of the trim during abatement. Walls were enclosed by drywall, then painted, and steel panels were placed on the walls in the stairwells. There were two phases to the lead clearance process: worker entry clearance and re-occupancy clearance. During worker entry clearance, the first phase, clearance samples were collected after protected workers had finished the abatement job. The clearance samples collected during the second phase, the re-occupancy cleanup, were taken after the renovation was completed but before the unit was reoccupied. Only samples collected during the second phase, or re-occupancy cleanup, were available and used in the analysis for this report. Within each completed unit, one dust sample was collected from each room or area where abatement occurred. Sample locations were randomly distributed between floors and window troughs. Since the abatement process included removal of many windows, few window sill and window trough samples were tested. The HUD Interim Guidelines Clearance Standards thresholds of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs were utilized in determining whether dust wipe

samples passed or failed. In all cases where results exceeded the clearance thresholds, the areas were re-cleaned and re-tested until acceptable results were obtained.

4.6 CLEVELAND LEAD HAZARD ABATEMENT CENTER

The lead abatement program managed by the Cleveland Lead Hazard Abatement Center jointly with the Cleveland Department of Public Health Environmental Health Watch recruited houses where children with elevated blood lead levels lived [19]. Most of the units were large single- family houses built before 1950. The level of intervention depended on the age and number of children in the house. Many of the homes were completely abated. Chipped paint was wet sanded and repainted with a primer and a coat of paint. Carpets were removed and the floors refinished. Windows were replaced in some units. Vinyl siding was applied to homes with lead-based painted wood siding. Porches were repaired, deteriorated sections replaced, and other surfaces scraped and repainted. If lead levels in the soil were high, the soil was removed and replaced. Sod, woodchips, or some other form of landscape coverage was placed over the exposed soil. This project was continuing at the time of the data analysis for this report.

4.7 DOVER HOUSING AUTHORITY, NEW HAMPSHIRE

One-hundred and eighty-four units in 49 multi-family buildings were abated and renovated [20]. Forty-three of the buildings had four units per building while the other six buildings had two units per building. The exterior siding and window sashes of the buildings contained lead-based paint, so siding and windows were removed and replaced. Interior lead-based paint was found only on water radiators. Thirty-one of the units had cast iron radiators. The radiators were removed from the apartments, sand blasted, off-site repainted, and reinstalled. Even though there was very limited abatement activity inside the units, dust wipe samples from the window trough and sill along with floor samples were collected for lead clearance following cleaning of the work area. The HUD Interim Guidelines Clearance Standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs were utilized in determining whether dust wipe samples passed or failed.

5.0 DATA METHODOLOGY AND ANALYSIS

The four objectives listed in Section 1 were addressed in the statistical analysis of the clearance sampling dust-lead loading results for each source of data separately. The statistical methods corresponding to each of these objectives are discussed below.

5.1 OBJECTIVE 1: CHARACTERIZATION OF THE NUMBER OF INDIVIDUAL SAMPLES, WORK AREAS, AND HOUSING UNITS THAT PASS OR FAIL CLEARANCE TESTING STANDARDS

The clearance testing data investigated in this analysis represent post cleanup dust-lead loading results of wipe samples collected from floors, window sills, and window troughs in and around abatement work areas. The samples were collected and chemically analyzed as individual samples. For the purposes of this analysis, the dust lead loading results from all data sources were assumed to represent a clearance testing program which compared lead loading results to the HUD Interim Guidelines Clearance Standards. The dust lead loading results were compared to clearance standards of 200 $\mu g/ft^2$ for bare floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. When a unit failed clearance, additional cleanup was performed. For those units that failed, a second site visit followed the first site visit, with cleanup and sampling being performed generally only in the areas which failed clearance standards. Results of these sample analyses determined whether the unit passed or failed clearance at this stage. Data were available for up to five visits for some residences. However, there were very few dust-lead loading results after the third site visit, so statistical results for the fourth and fifth site visits are not considered reliable in most cases.

Within each clearance testing program investigated, an analysis was conducted to summarize the results of clearance testing with regard to the HUD Interim Guidelines Clearance Standards. This analysis was designed to provide answers to the following questions:

1. During each site visit, how many individual samples passed/failed clearance?

    1a. During each site visit, how many floor samples passed/failed clearance?

    1b. During each site visit, how many window sill samples passed/failed clearance?

1c. During each site visit, how many window trough samples passed/failed clearance?

2. During each site visit, how many work areas (rooms) passed/failed clearance testing?

   2a. During each site visit, how many work areas would have passed/failed clearance based only on floor sample results (ignoring results from window sills and window troughs)?

   2b. During each site visit, how many work areas would have passed/failed clearance based only on window sill sample results (ignoring results from floors and window troughs)?

   2c. During each site visit, how many work areas would have passed/failed clearance based only on window trough sample results (ignoring results from floors and window sills)?

3. During each site visit, how many housing units passed/failed clearance testing?

   3a. During each site visit, how many housing units would have passed/failed clearance based only on floor sample results (ignoring results from window sills and window troughs)?

   3b. During each site visit, how many housing units would have passed/failed clearance based only on window sill sample results (ignoring results from floors and window troughs)?

   3c. During each site visit, how many housing units would have passed/failed clearance based only on window trough sample results (ignoring results from floors and window sills)?

4. After all sampling was completed, how many individual samples, work areas, and housing units passed/failed clearance?

   4a. After all sampling was completed, how many samples, work areas, and housing units passed/failed clearance based only on floor sample results (ignoring results from window sills and window troughs)?

   4b. After all sampling was completed, how many samples, work areas, and housing units passed/failed clearance based only on window sill sample results (ignoring results from floors and window troughs)?

   4c. After all sampling was completed, how many samples, work areas, and housing units passed/failed clearance based only on window trough sample results (ignoring results from floors and window sills)?

For each source of data, specific subsets of data were used to summarize the answers to these questions. These subsets are represented in Table 5-1. Each cell in Table 5-1 corresponds to a specific subset of data; the question which the data in a given cell addresses is indicated within the cell.

The preliminary analyses also suggested that for the majority of the data, only one sample of each component type was sampled following cleanup in most of the abated work areas. Thus, with regard to the responses to the above questions, Questions 1a, 1b, and 1c are essentially equivalent to questions 2a, 2b, and 2c within each site visit for each source of data.

Table 5-1. Location of Answers to Questions on Pass/Fail Rates.

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		# Pass	# Fail	Total	# Pass	# Fail	Total	# Pass	# Fail	Total
A Specific Site Visit	Floors	1a	1a	1a	2a	2a	2a	3a	3a	3a
	Sills	1b	1b	1b	2b	2b	2b	3b	3b	3b
	Troughs	1c	1c	1c	2c	2c	2c	3c	3c	3c
	All	1	1	1	2	2	2	3	3	3
All Site Visits Combined	Floors	4a	4a	4a	4a	4a	4a	4a	4a	4a
	Sills	4b	4b	4b	4b	4b	4b	4b	4b	4b
	Troughs	4c	4c	4c	4c	4c	4c	4c	4c	4c
	All	4	4	4	4	4	4	4	4	4

There are many factors that can influence the number of clearance samples that are collected from within a residential unit (size of house, extent of lead hazard, extent of abatement and sampling protocol). However, information on these factors was generally not available for this statistical analysis. A similar, related question of interest is: Does the probability that a housing unit will fail clearance testing increase as the number of clearance dust-wipe samples collected increases? Four logistic regression models were used to answer this question. The first logistic regression model was developed to estimate the probability of a housing unit failing clearance as a function of the number of samples collected. The model appears as:

$$\text{Logit}(\pi_i) = \beta_0 + \beta_1 * n_i$$

where

logit ( ) is the logit function, logit (P) = log (P/(1-P))

π_i is the expected probability of clearance failure for the i^{th} housing unit,

n_i is the number of clearance samples collected in the i^{th} housing unit,

β_0 is the intercept parameter, and

β_1 is the slope parameter.

For the second logistic regression model the numbers of samples collected within a housing unit were collapsed into five successive categories, as follows:

$$\text{Logit}(\pi_i) = \beta_0 + \beta_1 * c_i$$

where

c_i is the categorized number of samples collected in the i^{th} housing unit, where c_i ranges in values from 1 to 5 as n_i takes on values of (1-4 samples, 5-8 samples, 9-12 samples, 13-16 samples, and greater than 16 samples) respectively, and

π_i, β_0 and β_1 are defined the same as in the previous logistic regression model.

Both models were applied to clearance testing data collected during the first site visit, and were fitted both over all component types and separately for each component type (floors, sills, and troughs).

The third and fourth logistic regression models are similar to those described above but were developed using the proportion of samples that failed within a housing unit as the response variable. π_i was defined as the proportion of dust wipe samples expected to fail clearance testing in the i^{th} housing unit.

Tables were generated that provide estimates of β_0 and β_1, and the associated standard errors as well as the estimated probability of failing clearance (or estimated proportion of samples expected to fail) associated with a housing unit which collected 2, 4, and 6 wipe samples of the associated component type.

5.2 OBJECTIVE 2: CHARACTERIZATION OF THE DISTRIBUTION OF THE DUST-LEAD LOADINGS, GEOMETRIC MEAN DUST-LEAD LOADINGS, VARIABILITY WITHIN A HOUSING UNIT, AND VARIABILITY BETWEEN HOUSING UNITS

As shown in Figure 5-1 below, the distribution of the clearance sample results tends to have a small number of extremely large values. These large dust loading sample observations are thought to be the result of many minor influences which combine in a multiplicative way. The multiplicative influences have a greater effect on large dust-lead loadings than on smaller values. In situations where the error has a multiplicative effect on the true lead level, a natural logarithm transformation (ln-transformation) is recommended prior to performing parametric statistical procedures based on normally distributed data. If the distribution of the dust-lead loading clearance sample results is log-normal, then the actual ln-transformed results will be normally distributed. Histograms of the ln-transformed floor, window sill, and window through dust-lead loading data are given in Figures 5-2, 5-3, and 5-4, respectively. The normal distribution has been overlaid on the empirical distribution. The spike in the plot in Figure 5-2 between 1 and 2 on the x-axis is likely due to a large number of results reported at the detection limit. Review of the data for floor samples suggested that the detection limit for these samples varied from 5 to 25 micrograms per square foot ($\mu g/ft^2$). Except for the spike that appears in Figure 5-2, the log-normality assumption appears to be reasonable for these data. None of the inferential statistical protocols in this report are overly sensitive to the assumption of log-normality. Therefore, the statistical models used in this report are based on the natural logarithm transformed dust-lead loadings.

Because the dust-lead clearance sample results were assumed to follow the log-normal distribution, the geometric mean was used as the measure of central tendency. (The geometric mean is the inverse-logarithm transformation of the arithmetic mean of the ln-transformed dust-lead clearance samples.)

For each data source separately, the following statistical model was applied to the dust-lead loading results to characterize within-unit (σ_{Within}) and between-unit ($\sigma_{Between}$) variability. It was fitted separately for each combination of site visit (j = 1, 2, or 3) and component type (l = floors, window sills, or window troughs) (i.e. levels of j and l were held fixed):

$$\ln(PbD_{ijklm}) = \log(\mu_{(jl)}) + \text{House}_{i(jl)} + \text{Error}_{ikm(jl)}$$

where

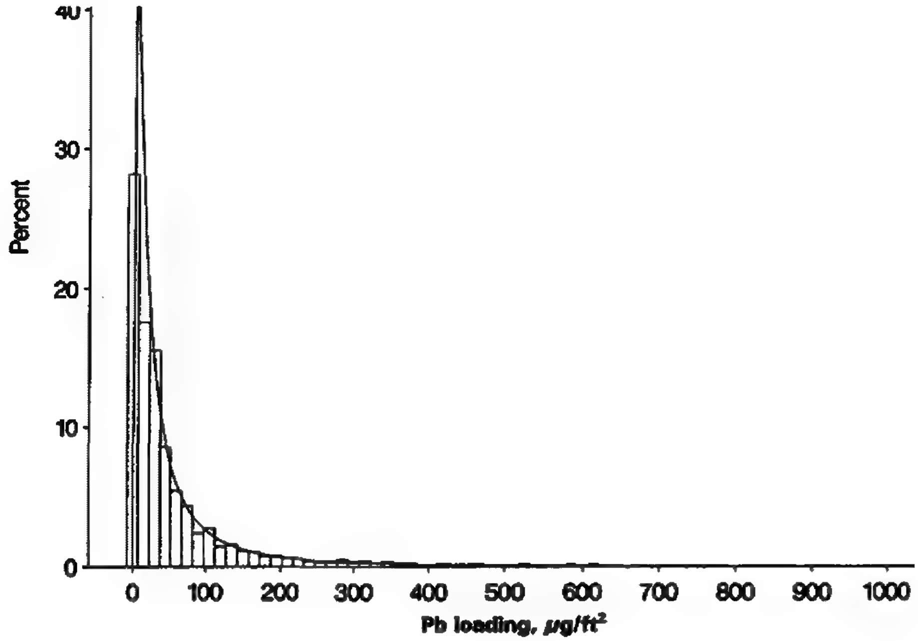


Figure 5-1. Histogram of Dust Lead Loadings from Floor Samples.

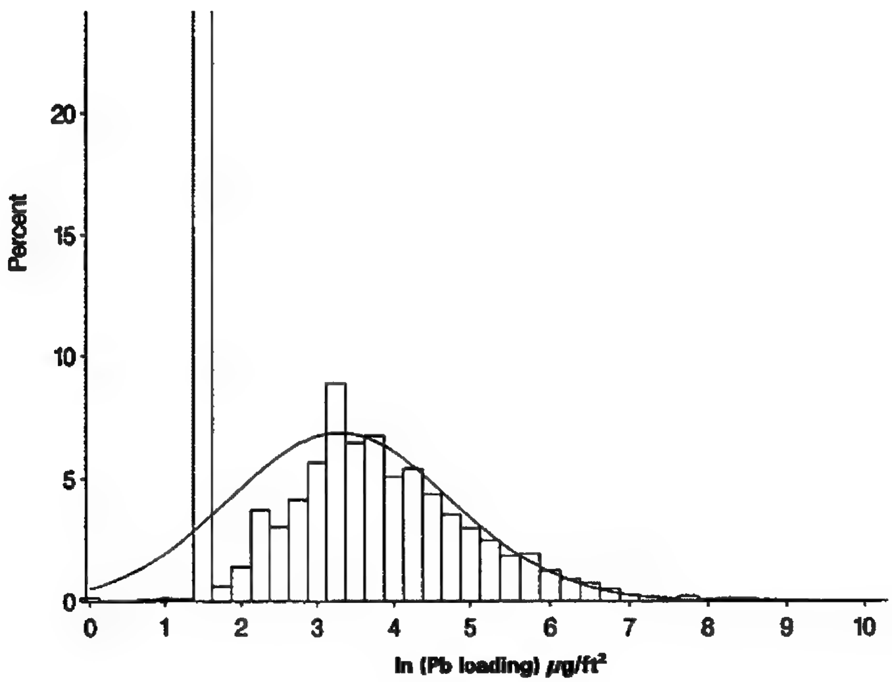


Figure 5-2. Histogram of the Natural Logarithm of Dust Lead Loadings from Floor Samples.

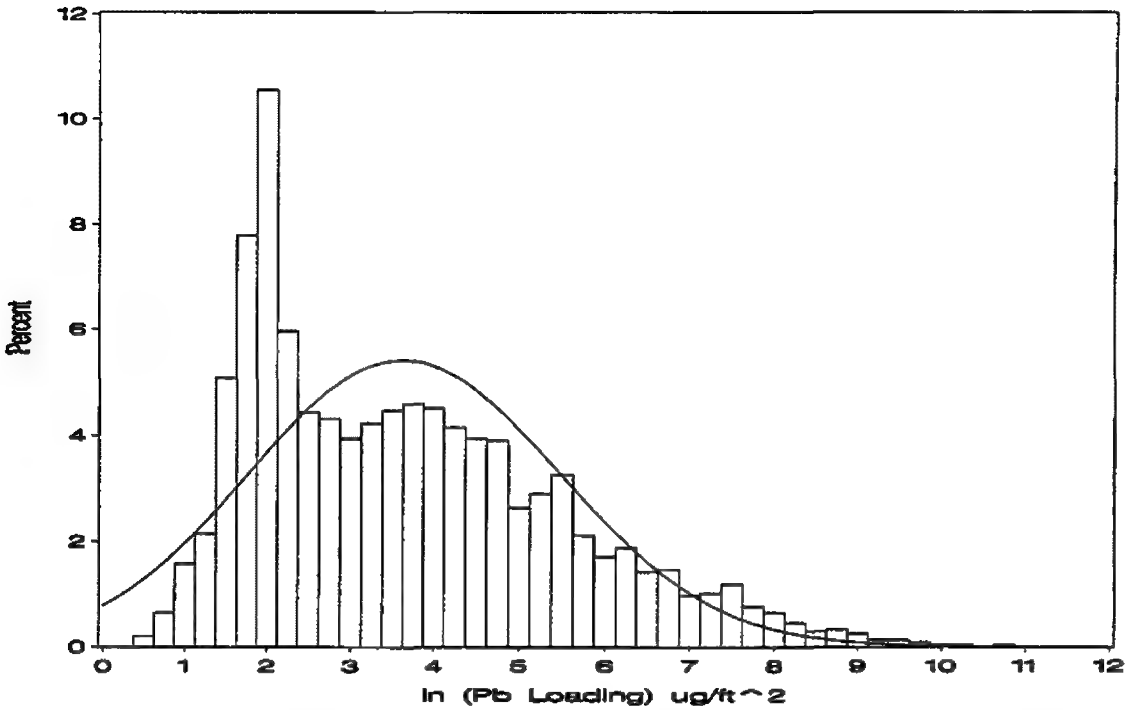


Figure 5-3. **Histogram of the Natural Logarithm of Dust Lead Loadings from Window Sill Samples**

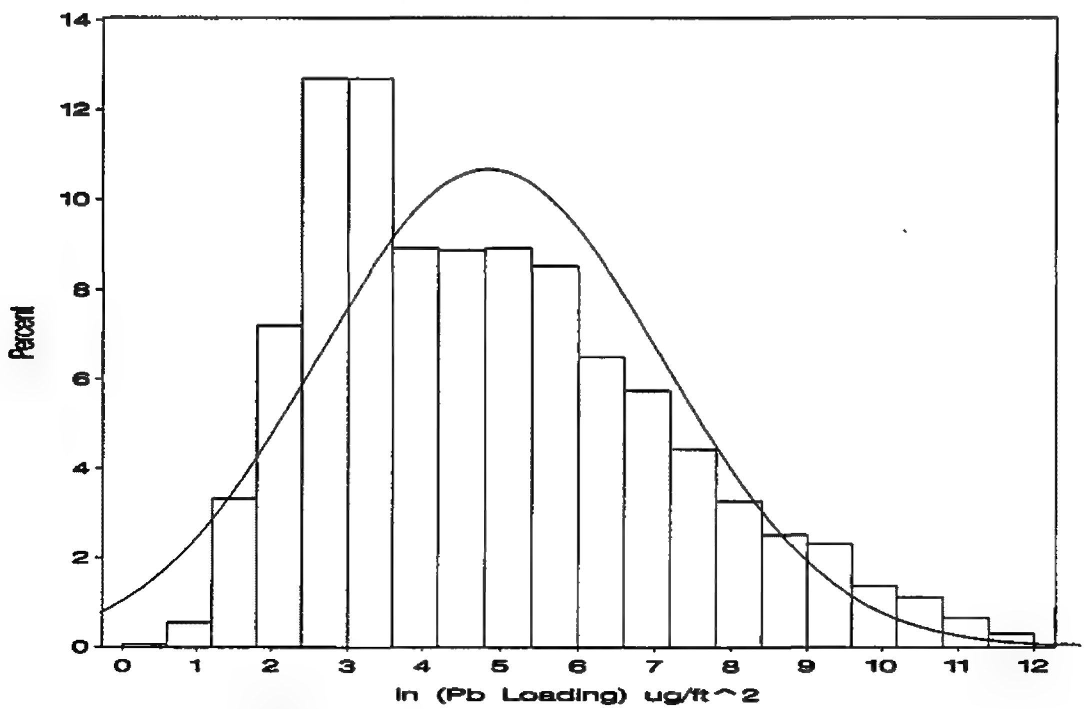


Figure 5-4. **Histogram of the Natural Logarithm of Dust Lead Loadings from Window Trough Samples**

$\mu_{(jl)}$	=	geometric mean dust-lead loading across housing units for site visit j and component l,
$House_{i(jl)}$	=	random effect for the average log(dust-lead loading) within housing unit i for site visit j and component l,
$Error_{ikm(jl)}$	=	random (within house) error term associated with $\log(PbD_{ijklm})$,
$i=1...,N$	=	N = the number of housing units sampled,
$k=1,...,K_i$	=	K_i=the total number of work areas sampled in unit i,
$m=1,...,M_{ijkl}$	=	M_{ijkl} = the number of replicate samples of component l collected in work area k of housing unit i during the j^{th} site visit.

$House_{i(jl)}$ is assumed to follow a normal distribution with mean zero and standard deviation $\sigma_{Between}$. $Error_{ikm(jl)}$ is assumed to follow a normal distribution with mean zero and standard deviation σ_{Within}. (Note: Because very few results were recorded for the fifth site visits, the analysis was performed using only the information provided for the first, second, third, and fourth site visits.)

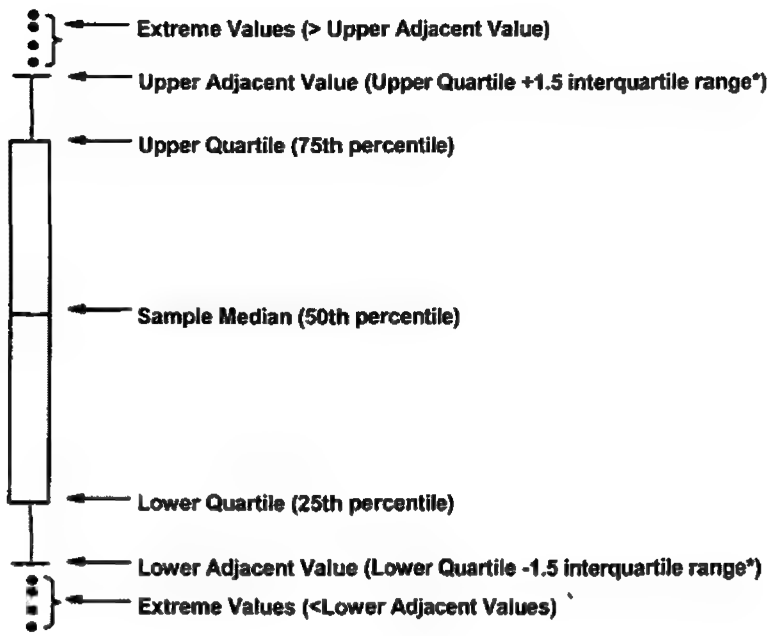
The analysis is based on three methods of assessing the distribution of the individual dust lead loading samples:

1. Consider the 50th, 80th, 90th, 95th, and 99th percentiles of the dust wipe samples for the first or initial site visit and the final site visit,

2. Consider the percentage of individual dust wipe sample results that fell below 50, 75, and 100 $\mu g/ft^2$, and the interim standard for each surface, and

3. Consider box and whisker plots for each surface type and for the dust wipe samples collected during the first site visit and the dust wipe samples collected during the site visit that passed clearance.

Box and whisker plots describe the distribution of the data in the following manner.



*Interquartile range is the distance between the upper quartile and the lower quartile.

5.3 OBJECTIVE 3: CHARACTERIZATION OF THE CORRELATION BETWEEN COMPONENTS SAMPLED IN THE SAME WORK AREA

As part of the clearance testing procedure, some dust-wipe samples were collected from floors, window sills, and window troughs from the same abatement work areas following cleanup. Although the clearance standards are different for dust samples of different component types, it is reasonable to hypothesize that clearance samples collected from different component types within the same work area are positively correlated. Estimated correlation coefficients between component types from within the same room were calculated using natural log transformed (ln-transformed) area weighted average dust-lead loading results. Since there may be multiple samples collected within the same room for a component type, area weighted average dust-lead loadings were needed in the calculation of correlation coefficient between component types. The correlation coefficients were estimated separately for each site visit within each source of data.

In addition to characterizing the correlation between the different components tested within a room, it was informative to characterize the probability that one component would pass

(or fail) given that another component in the same room either passed or failed. This type of information could be used to determine whether it is necessary to sample from all three component types within a single work area or room. These conditional probabilities were calculated in two ways using first-site-visit data only, first by empirical evaluation of 2×2 tables, and second by using normal probability theory.

To illustrate the use of these two approaches, an example is provided for calculating the conditional probability that a floor would pass clearance given that a window sill in the same room passed clearance. Both methods require that the first site visit data be organized to include paired observations of floors and sills observed in the same room:

> Floor_{ij} represents the geometric mean floor lead loading in the j^{th} room of the i^{th} housing unit, and
> Sill_{ij} represents the geometric mean window sill lead loading in the j^{th} room of the i^{th} housing unit.

The empirical evaluation of 2×2 tables would then organize this data in the following manner:

	$\text{Floor}_{ij} < 200\ \mu g/ft^2$	$\text{Floor}_{ij} \geq 200\ \mu g/ft^2$
$\text{Sill}_{ij} < 500\ \mu g/ft^2$	a	b
$\text{Sill}_{ij} \geq 500\ \mu g/ft^2$	c	d

where 'a' represents the number of rooms in which both the floor and window sill passed clearance, 'b' represents the number of rooms in which the sill passed and the floor failed, 'c' represents the number of rooms in which the floor passed and the sill failed, and 'd' represents the number of rooms in which both the floor and the sill failed clearance. Thus, the conditional probability that a floor would pass clearance given that a window sill in the same room passed clearance would be estimated as a/(a+b).

For the second approach, using the multivariate normal theory approach [21], the data would be organized as follows:

$$\begin{bmatrix} \ln(Floor_{ij}) \\ \ln(Sill_{ij}) \end{bmatrix} \sim N\left\{ \begin{bmatrix} \mu_F \\ \mu_S \end{bmatrix}, \begin{bmatrix} \sigma_F^2 & \sigma_{FS}^2 \\ & \sigma_S^2 \end{bmatrix} \right\}$$

Modeling the multivariate distribution between floors, window sills, and window troughs using the multivariate normal distribution provides interested parties the means of estimating these conditional probabilities without having to directly access the data.

The parameters of the above multivariate normal distribution are calculated using the observed ($Floor_{ij}$, $Sill_{ij}$) pairs. The conditional distribution of floor dust-lead loading given sill dust-lead loading is

$$\ln(Floor)|\ln(Sill) \sim N(\mu_F + \frac{\sigma_{FS}^2}{\sigma_S^2}(\ln(Sill)-\mu_S)\ ,\ \sigma_F^2 - \frac{(\sigma_{FS}^2)^2}{\sigma_S^2}\ )$$

If $f_{F|S}(f,s)$ is defined as the density function of the above normal distribution, then using standard normal theory the conditional probability of a floor passing clearance given that a window sill in the same room passed clearance would be estimated as

$$P(Floor < 200\mu g/ft^2 \mid Sill < 500\mu g/ft^2) = \frac{\int_{-\infty}^{\ln(200)} \int_{-\infty}^{\ln(500)} f_{F,S}(f,s)ds\,df}{\int_{-\infty}^{\infty} \int_{-\infty}^{\ln(500)} f_{F,S}(f,s)ds\,df}$$

We also applied similar methods for calculating more complicated conditional probabilities, such as the conditional probability of a floor passing clearance given that a window sill and trough in the same room passed clearance.

5.4 OBJECTIVE 4: DEMONSTRATION OF THE IMPACT OF COMPOSITE SAMPLING ON PASS/FAIL RATES OF HOUSES

Under EPA's Section 402 Rule (40 CFR Part 745) [4], composite sampling of dust is permitted for clearance following an abatement. Additionally, the HUD Guidelines indicate that

composited dust samples may be used for conducting clearance testing. A composite wipe sample is a group of individual wipe samples collected from multiple locations of the same component type, which are combined into a single analytical sample. Thus, a composite sample result could be interpreted as the (area weighted) average dust-lead loading across all locations included in the sample.

Analytical results from composite samples have different statistical properties from those for individual samples. For example, error associated with lead loading results from composited wipe samples differs from error associated with lead loadings found in individual wipe samples. The error attributed to spatial variability in sampling is reduced in composite samples, due to the averaging of multiple sampling locations. Differences between individual and composite samples with regard to variability caused by laboratory measurement error has not yet been established. However, due to the reported difficulties in digesting large numbers of dust wipes for chemical analysis, it is recommended [3] that composite wipe samples contain at most four wipes, thereby limiting the number of sampling locations to at most four.

As an example of the difference in statistical interpretation between a composite sample and individual samples, consider four individual floor wipe samples with lead loadings of 150, 175, 100, and 275 $\mu g/ft^2$, each collected from one square foot. If the composite sample is the area weighted average of these four loadings, then the composite lead loading result would be 175 $\mu g/ft^2$. If the clearance testing is based solely on the composite sample, the home would pass at the clearance level of 200 $\mu g/ft^2$. Yet, if the individual samples were used for clearance testing, the home would fail based on the sample at 275 $\mu g/ft^2$.

5.4.1 Construction of the Simulated Composite Samples

Because most of the samples were collected during the first site visit, only the first site visit individual samples were considered for the composite sample analysis. During the first site visit, often more than four dust wipe samples were collected from a single component type within a housing unit. For example, in clearance testing from the Maryland Department of the Environment, the number of individual floor samples collected from each housing unit during the first site visit ranged from one to fifteen. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples. Therefore, in the cases of 1 to 4 individual samples collected within a housing unit for a

component type, these 1, 2, 3, or 4 individual samples were considered as one single simulated composite sample. Even when there was only one individual sample collected within a housing unit for a component type, this individual sample was still considered as one simulated composite sample in the analysis. When five or more individual samples from a certain component type were collected within a housing unit, multiple simulated composite samples were created. For example, consider five floor samples, 100, 150, 175, 150, and 250 $\mu g/ft^2$, that were collected in a home. Two composite samples could be created, one with four samples and one with one sample. For the five samples, five different combinations could be used to create the two composite samples:

EXAMPLE 1:

Combination	Composite Sample 1 (Individual Sample Loadings)	Composite Sample 1 (Average Loading for Composite)	Composite Sample 2 (Loading for Individual Sample)
1	100, 150, 175, 150	143.75	250
2	150, 175, 150, 250	181.25	100
3	175, 150, 250, 100	168.75	150
4	150, 250, 100, 150	162.50	175
5	250, 100, 150, 175	168.75	150

Therefore, 2 simulated composite samples could be constructed in the cases of 5, 6, 7, or 8 individual samples which were collected within a housing unit for a component type: one with four individual samples and the other one with 1, 2, 3, or 4 individual samples, respectively. To construct 3 simulated composite samples, 9 to 12 individual samples were needed. In the cases of 9 individual samples collected within a housing unit for a component type, 3 simulated composite samples would be constructed: two simulated composite samples each would have 4 individual samples and the third simulated composite sample would have only one individual sample. As many as 630 different combinations could be constructed from the 3 simulated composite samples for the cases of 9 individual samples collected within a housing unit for a component type.

The different combinations or multiple composite samples that are possible add another level of complexity to the analysis of composite samples which must be addressed. Each combination can result in a different outcome (pass/fail).

5.4.2 Composite Sample Clearance Criteria

Since composite samples can pass the HUD Interim Guidelines Clearance Standards when one or more individual samples within the composite fail the standards, it is important to compare and assess the failure rate of composite samples under different clearance criteria. Three criteria were evaluated in this report and are as follows:

Criterion 1: Standard Rule

The first criterion states that a composite sample will pass clearance only if its lead loading is less than the corresponding clearance standard for individual samples. This criterion, referred to as the "Standard Rule," implies that the average lead-loading for all subsamples included in the composite sample must be lower than the individual sample clearance standard for the given component in order to pass clearance. For instance, in Example 1 above, only Composite Sample 2 in Combination 1 will fail the home. All other composite samples would be below 200 $\mu g/ft^2$, passing the clearance standard under this criterion. Because this criterion only considers the overall result of the composite sample, it is liberal in that it will often allow individual locations to pass clearance testing, even though certain subsamples may have loadings that exceed the standards.

Criterion 2: Standard/n Rule

The second criterion allows a composite sample to pass clearance only if the lead loading result is less than the corresponding standard for individual samples divided by the number of subsamples in the composite sample. Thus, assuming all subsamples represent equal surface areas, the total amount of lead in all subsamples must be lower than the individual sample clearance standard. For example, 200 $\mu g/ft^2/4 = 50$ $\mu g/ft^2$. For instance, using Example 1, the home would fail floor clearance testing because of both Composite Samples in Combination 1, and because of Composite Sample 1 for all the rest of the combinations. This criterion, referred to as the "(Standard/n) Rule", is conservative in that a composite sample result can fail the criterion even though all subsamples may have had lead loadings that were below the standards for individual samples. The "(Standard/n) Rule" will never pass a composite sample result whenever at least one single subsample has a lead loading which exceeds the individual sample standard.

Criterion 3: 2xStandard/n Rule

The third criterion is a compromise between the liberal "Standard Rule" and the conservative "(Standard/n) Rule." This criterion states that if a composite sample consists of n subsamples (where $2 \leq n \leq 4$), its lead loading must be less than the corresponding individual sample clearance criterion multiplied by 2/n. For example, 2 x 200 $\mu g/ft^2/4$ = 100 $\mu g/ft^2$. In Example 1, the home fails clearance testing in all cases. This criterion, referred to as the "(2×Standard/n) Rule", will result in fewer false clearance passes than the "Standard Rule," and fewer false clearance failures than the "(Standard/n) Rule."

To assess the effect of the different composite combinations on the pass/fail outcome for a home, the probability of a home passing clearance was calculated under the different criteria, considering all the possible combinations of composite samples. Note that the compositing was done separately for each component type since actual composite samples would not contain subsamples from different component types. Also, for calculating the simulated composite samples an assumption was made that all dust samples from a given component type within a home were collected from equal sized surface areas.

For various examples of hypothetical data for individual samples, Table 5-2 presents the pass probability associated with each of the three composite sample clearance criteria when considering all possible ways to construct multiple simulated composite samples.

5.4.3 Methods for Summarizing the Simulated Composite Sample Results

The statistical methodologies discussed in this subsection were used to summarize the simulated composite sample results. These methods, frequency table performance characteristics and logistic regression, were applied separately to each combination of component type and composite clearance criteria.

For each combination of component type and clearance criterion, the simulated composite sample results within each housing unit were categorized into three groups: those that passed clearance (Pr(Pass)=1), those that failed clearance (Pr(Pass)=0), and those that were inconclusive (0<Pr(Pass)<1) based on results for all possible composite sample combinations. For example, in Example 1 in Section 5.4.1, the housing unit which had those five floor samples would be categorized as "inconclusive." While one of the combinations of the simulated composite samples failed clearance based on a floor standard of 200 $\mu g/ft^2$ (Combination 1, the second

Table 5-2. The Probability of Passing Each of the Three Composite Sample Clearance Criteria Based on Multiple Simulated Composite Samples Constructed from Hypothetical Sample Data.

Component Tested	Individual Sample Clearance Standard	Observed Individual Pb Loading Results ($\mu g/ft^2$)	Number of Ways to Construct Two Composite Samples	Probability of Passing a Housing unit Based on All Possible Combinations of Simulated Composite Sample Results		
				Standard Rule	(Standard/n) Rule	(2 × Standard/n) Rule
Floors	200 $\mu g/ft^2$	25, 50, 50, 70, 175	5	1	0.2	1
		50, 50, 75, 100, 150, 240	15	1	0	0.4
		90, 100, 150, 175, 250, 300	15	0.33	0	0
		75, 75, 100, 150, 200, 250, 300	35	0.63	0	0
		75, 75, 100, 100, 150, 200, 250, 300	70	0.8	0	0
Window Sills	500 $\mu g/ft^2$	100, 100, 200, 300, 600	5	0.8	0	0.8
		300, 400, 400, 450, 450	5	1	0	0
		250, 300, 350, 350, 450, 700	15	0.73	0	0
		400, 450, 500, 550, 600, 800	15	0	0	0
		100, 100, 100, 150, 200, 800, 900	35	0.74	0	0
Window Troughs	800 $\mu g/ft^2$	350, 350, 400, 600, 750	5	1	0	0.4
		100, 625, 850, 850, 900	5	0.2	0	0
		300, 400, 400, 600, 900, 1200	15	0.73	0	0
		50, 100, 100, 250,300, 700	15	1	0.07	0.73
		150, 150, 150, 150, 150, 150, 3500	35	0	0	0

composite sample = 250 µg/ft^2), the other 4 combinations of simulated composite samples passed clearance. This resulted in inconclusive determination of failing or passing clearance for this house, based on the construction of multiple simulated composite samples. Inconclusive results were only possible for those housing units which contained more than four individual samples; the many possible ways of combining five or more individual sample lead-loadings into multiple simulated composite samples had the potential of resulting in a variety of different outcomes under each of the three composite clearance criteria, and therefore, "inconclusive" results.

Performance Characteristics

Frequency tables were generated to compare the clearance testing outcome within a residential unit based on simulated composite clearance results versus individual sample clearance results. An example of such a table is found in Table 5-3. Consider the cell labeled 'b'. The value of 'b' indicates the number of units that would pass clearance based on analysis of simulated composite samples, but would fail clearance had the results for individual subsamples been considered.

Table 5-3. Table Summarizing Pass/Fail Conclusions Made from Individual Sample Clearance Results Compared to the Simulated Composite Sample Results.

		Individual Samples	
		Pass	Fail
Simulated Composite Samples	Pass	a	b
	Inconclusive	c	d
	Fail	e	f

A quantifiable method for evaluating the comparison of the individual sample results to the simulated composite results is to assess the performance characteristics of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Using the structure of Table 5-3, the performance characteristics are calculated as follows:

Sensitivity = Probability of a dwelling unit failing clearance testing based on simulated composite samples given that the unit would have failed clearance testing based on the results of individual samples. Sensitivity is estimated by f/(b+d+f).

Specificity = Probability of a dwelling unit passing clearance testing based on simulated composite samples given that the unit would have passed clearance testing based on the results of individual samples. Specificity is estimated by a/(a+c+e).

PPV = Probability of a dwelling unit failing clearance testing based on individual samples given that the unit would have failed clearance testing based on the results of composite samples. PPV is estimated by f/(e+f).

NPV = Probability of a dwelling unit passing clearance testing based on individual samples given that the unit would have passed clearance testing based on the results of composite samples. NPV is estimated by a/(a+b).

Contrary to the classical epidemiological use of these measures, the performance characteristics do not include any measures of actual lead exposure. Rather they compare the performance of each composite sample criterion to the clearance decision based on individual sample clearance testing results.

The performance of the simulated composite samples was made using the epidemiological terms of sensitivity, specificity, NPV and PPV because an appropriate composite sample clearance criterion could then be selected based on maximizing the epidemiological performance characteristics. Such a composite criterion would result in less costly clearance testing and clearance decisions, while making decisions similar to those based on individual samples. On the other hand, certain performance statistics may be of higher importance than others. For example, to protect children from potential lead exposure, one may decide to maximize the sensitivity of the composite clearance criteria while sacrificing higher specificity.

Logistic Regression

All three composite clearance criteria have different specificity and sensitivity error rates. These rates correspond to the consistency between clearance decisions and the true lead hazards

present in the various locations included as part of the composite sampling scheme. Since clearance testing is a procedure that is used to ensure that unprotected workers and residents are not exposed to lead contaminated media following an environmental intervention, the performance of each composite clearance criterion was characterized based on the maximum lead hazard that is likely to be left behind. This was done by estimating pass probabilities as a function of the maximum lead loading result.

Logistic regression models were developed that estimated the probability of passing clearance within a housing unit (as estimated by the simulated composite sample results) based on the maximum individual sample lead-loading result. This model appears as follows:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where

logit ( ) is the logit function, logit (P) = log (P/(1-P))

π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k),

Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j),

β_0 is the intercept parameter, and

β_1 is the slope parameter.

Tables were generated that give the estimates of β_0 and β_1, and associated standard errors from the logistic regression models, as well as estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is equal to ½, 1, 2, and 4 times the associated HUD Interim Guidelines Clearance Standard for individual samples. Figures were also produced that illustrate the relationship between the probability of passing clearance (using composite samples) and the maximum lead loading among all locations included in the simulated composite samples.

6.0 FINDINGS AND RESULTS

Based on the analysis methods outlined in Section 5.0, data from seven data sources were analyzed and discussed in this chapter. For the HUD Grantee data, two analyses were performed: one for a group of combined grantees that used the HUD Interim Guidelines clearance standards (i.e., 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively); the other for a group of combined grantees that used a lower floor dust-lead clearance standard. The first group includes Alameda County, Baltimore, Boston, California, Massachusetts, Milwaukee, Rhode Island, Vermont, and Wisconsin. The second group includes Cleveland, Chicago, New Jersey, and New York City, which use 100 $\mu g/ft^2$ as floor dust-lead clearance standard, and Minnesota which uses 80 $\mu g/ft^2$. The first group is labeled as "HUD Grantee (High)"; the second group is labeled as "HUD Grantee (Low)" in the analysis summary tables in this chapter. Altogether, analysis results from eight data groups are discussed: data from Maryland, HUD FHA, HUD PHA, HUD Grantee (High), HUD Grantee (Low), Atlantic City, Cleveland, and Dover.

The range of analysis results across data sources are summarized and discussed in the following four subsections. The analysis results on the individual data sources are provided in Appendices A through G.

Unless otherwise noted, the clearance standards used for the analyses in this report are the numerical standards in the HUD Interim Guidelines clearance standards. That is, clearance standards are 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively.

6.1 OBJECTIVE 1: CHARACTERIZATION OF THE NUMBER OF INDIVIDUAL SAMPLES, WORK AREAS, AND HOUSING UNITS THAT PASS OR FAIL CLEARANCE TESTING STANDARDS

Tables 6-1a to 6-1e present the number of samples, rooms, and housing units in which the clearance criteria for individual samples were met ("Pass") or were not met ("Fail") for a given site visit and component type. Table 6-1f presents similar results for all site visits combined. In addition, the number of samples, rooms, and housing units sampled are provided in the "Total" column. Tables 6-1g to 6-1i provide similar results as Table 6-1a for the first site visit data only, except that while in Table 6-1a, pass/fail was based on HUD Interim Guidelines clearance standards, in Tables 6-1g, 6-1h, and 6-1i, pass/fail was based on various floor, window sill, and window trough clearance standards.

As seen in Table 6-1a, for the first site visit and all components tested, across eight data sources, 2.7% to 20.8% of the individual dust samples, 3.6% to 31.7% of the rooms, and 13.3% to 65.1% of the housing units failed the clearance standards. Note that if an individual sample did not meet the clearance standard, then the room and housing unit did not meet the standard. Yet, even if the individual sample passed clearance, the room or housing unit associated with the individual sample did not necessarily pass clearance. There were 35,800 dust wipe clearance samples collected in 4,487 housing units across eight data sources for the first site visit. On average, there were about 7.97 dust wipe clearance samples from each housing unit collected immediately after intervention.

The failure rate for individual samples during the first site visit for floor samples ranges from 2.1% to 18.8%, from 1.1% to 38.9% for window sill samples, and from 1.9% to 36.4% for window trough samples. For the first site visit, the failure rates for housing units based on the results solely from individual components were as follows: 3.4% to 56.5% of the housing units would have failed based on the results of window trough samples, 3.0% to 41.7% of the housing units would have failed based on the results of window sill samples, and 7.3% to 46.2% of the housing units would have failed based on the results of floor samples.

For houses that did not pass the clearance standard the first time, failure rates were higher for the subsequent site visits in some cases. This can be seen in Tables 6-1b to 6-1e, which present clearance testing results for the second, third, fourth, and fifth site visits, respectively. Table 6-1f presents clearance testing results for all site visits data combined. It shows that, for all components, across the eight available data sources, 2.7% to 26.1% of wipe dust-lead loading clearance samples failed the clearance standards, which resulted in 3.4% to 25.5% of the houses failing clearance.

As expected, Tables 6-1g to 6-1i show that the failure rate increased as the clearance standard was set lower. The failure rates for housing units were between 17.5% and 72.4%, 29.2% and 81.5%, and 36.2% and 87.4%, based on the floor standards at 100 $\mu g/ft^2$, 50 $\mu g/ft^2$, and 40 $\mu g/ft^2$, respectively. Based on window sill standards at 500 $\mu g/ft^2$, 250 $\mu g/ft^2$, and 125 $\mu g/ft^2$, the failure rates for housing units were between 3% and 41.7%, 12.4% and 83.3%, and 24.9% and 91.7%, respectively. Based on window trough standards at 800 $\mu g/ft^2$, the failure rates for housing unit were between 3.4% and 56.57%; at 400 $\mu g/ft^2$, they were between 5.5% and 69.4%.

The results of the logistic regression analyses for determining the probability of a housing unit failing clearance testing based on the number of samples collected for the housing unit are presented in Tables 6-2 through 6-5. In Table 6-2, many slope estimates for individual components and for all components together are positive and statistically significant. Several slope estimates are negative; however, they are not statistically significant. The positive slopes indicate an increase in the probability of the home failing clearance as the number of samples increases. The second half (right-hand side) of Table 6-2 shows that when two samples were collected, the estimated probability of failing clearance ranges from 0.04 to 0.49 for samples collected from floors, from 0.03 to 1.00 for window sill samples, from 0.03 to 0.41 for window trough samples, and from 0.16 to 0.50 for all three components combined. When 6 samples were collected, the estimated probability of a home failing clearance ranges from 0.11 to 0.44, from 0.04 to 1.00, from <0.01 to 0.71, and from 0.13 to 0.46 for samples collected from floors, window sills, window troughs, and all components, respectively.

Table 6-3 provides similar logistic regression results when considering the number of samples in categories of 1 to 4 samples and 5 to 8 samples collected. Table 6-3 also shows that many of the slope estimates are positive and significant. For three very negative slope estimates that were significant (-24.044 and -23.998 for window sills in Atlantic City and Cleveland data, and -21.247 for window troughs in Atlantic City data), almost all housing units in these cases passed clearance, regardless of the number of clearance samples collected. All other negative slope estimates are not significant. Within a housing unit when 1 to 4 samples are collected, Table 6-3 shows that the estimated probability of failing clearance ranges from 0.05 to 0.42 for samples collected from floors, from 0.03 to 0.42 for window sill samples, from 0.03 to 0.52 for window trough samples, and from 0.17 to 0.45 for all three components combined.

Tables 6-4 and 6-5 present the results of the logistic regressions run to predict the proportion of samples within a housing unit expected to fail clearance testing based on the number of samples collected. Table 6-4 shows that only the HUD Grantee Low data group presents any case of a positive and statistically significant slope estimate. The proportion of samples expected to fail clearance increases as the number of samples collected increases. All other significant slope estimates are negative, indicating in these cases that a greater proportion of samples pass clearance when more clearance samples are collected. Similar results are seen in Table 6-5: the HUD Grantee Low data group has the only case of a statistically significant

positive slope estimate when the number of samples is treated as a categorical variable. Note that many slopes are negative in Table 6-5; the estimated proportions of samples failing clearance testing tend to decrease as the number of samples increases in these cases. Overall, the estimated proportion of samples failing clearance ranged from 0.01 to 0.19 for floors, from 0.01 to 0.39 for window sills, from 0.01 to 0.44 for window troughs, and from 0.05 to 0.24 for all components when 1-4 samples were collected. When 5-8 samples were collected , the estimated proportions of samples failing clearance testing were ranging from 0.04 to 0.19 for floors, from <0.01 to 0.39 for window sills, from <0.01 to 0.32 for window troughs, and from 0.03 to 0.23 for all components.

Table 6-1a. Clearance Testing Results by Individual Sample, Room, and Housing Unit for the First Site Visit.

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor												
Maryland	2501	249	9.1	2750	2413	243	9.1	2656	521	140	21.2	661
HUD FHA	785	182	18.8	967	748	174	18.9	922	78	67	46.2	145
HUD PHA	501	57	10.2	558	443	47	9.6	490	88	31	26.1	119
HUD Grantee (High)*	7711	468	5.7	8179	7083	459	6.1	7542	1775	317	15.2	2092
HUD Grantee (Low)**	3486	156	4.3	3642	3410	154	4.3	3564	909	112	11.0	1021
Atlantic City	516	38	6.9	554	479	37	7.2	516	127	32	20.1	159
Cleveland	138	20	12.7	158	137	20	12.7	157	24	14	36.8	38
Dover	620	13	2.1	633	610	13	2.1	623	140	11	7.3	151
Window Sill												
Maryland	2211	254	10.3	2465	2121	250	10.5	2371	470	142	23.2	612
HUD FHA	578	90	13.5	668	576	88	13.3	664	80	46	36.5	126
HUD PHA	402	9	2.2	411	383	8	2.0	391	103	8	7.2	111
HUD Grantee (High)*	4601	197	4.1	4798	4394	196	4.3	4590	1854	177	8.7	2031
HUD Grantee (Low)**	2068	79	3.7	2147	2044	79	3.7	2123	897	71	7.3	968
Atlantic City	46	5	9.8	51	46	5	9.8	51	16	4	20.0	20
Cleveland	92	1	1.1	93	92	1	1.1	93	32	1	3.0	33
Dover	11	7	38.9	18	11	7	38.9	18	7	5	41.7	12

Table 6-1a. Continued

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Window Trough												
Maryland	1577	408	20.6	1985	1455	399	21.5	1854	337	199	37.1	536
HUD FHA	281	161	36.4	442	280	160	36.4	440	47	61	56.5	108
HUD PHA	364	7	1.9	371	349	7	2.0	356	105	5	4.5	110
HUD Grantee (High)*	2827	175	5.8	3002	2686	173	6.1	2859	1546	151	8.9	1697
HUD Grantee (Low)**	1228	118	8.8	1346	1221	118	8.8	1339	772	101	11.6	873
Atlantic City	252	6	2.3	258	248	6	2.4	254	114	5	4.2	119
Cleveland	37	2	5.1	39	37	2	5.1	39	22	2	8.3	24
Dover	260	5	1.9	265	256	5	1.9	261	141	5	3.4	146
All Components												
Maryland	6289	911	12.7	7200	2762	688	19.9	3450	402	304	43.1	706
HUD FHA	1644	433	20.8	2077	698	324	31.7	1022	52	97	65.1	149
HUD PHA	1267	73	5.4	1340	761	58	7.1	819	81	38	31.9	119
HUD Grantee (High)*	15139	840	5.3	15979	9508	791	7.7	10299	1608	524	24.6	2132
HUD Grantee (Low)**	6782	353	4.9	7135	4191	331	7.3	4522	796	229	22.3	1025
Atlantic City	814	49	5.7	863	714	48	6.3	762	121	39	24.4	160
Cleveland	267	23	7.9	290	173	23	11.7	196	23	15	39.5	38
Dover	891	25	2.7	916	679	25	3.6	704	137	21	13.3	158

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1b. Clearance Testing Results by Individual Sample, Room, and Housing Unit for the Second Site Visit.

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor												
Maryland	185	22	10.6	207	178	22	11.0	200	82	15	15.5	97
HUD FHA	152	82	35.0	234	141	78	35.6	219	34	36	51.4	70
HUD PHA	40	13	24.5	53	34	9	20.9	43	24	3	11.1	27
HUD Grantee (High)*	550	58	9.5	608	506	54	9.6	560	289	44	13.2	333
HUD Grantee (Low)**	226	19	7.8	245	216	19	8.1	235	131	16	10.9	147
Atlantic City	29	13	31.0	42	25	12	32.4	37	12	4	25.0	16
Cleveland	15	3	16.7	18	15	3	16.7	18	10	3	23.1	13
Window Sill												
Maryland	2211	25	12.9	194	164	23	12.3	187	67	11	14.1	78
HUD FHA	83	28	25.2	111	80	28	25.9	108	30	21	41.2	51
HUD PHA	10	0	0.0	10	10	0	0.0	10	9	0	0.0	9
HUD Grantee (High)*	261	20	7.1	281	255	20	7.3	275	190	19	9.1	209
HUD Grantee (Low)**	83	8	8.8	91	82	8	8.9	90	66	8	10.8	74
Atlantic City	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
Cleveland	1	0	0.0	1	1	0	0.0	1	1	0	0.0	1
Window Trough												
Maryland	227	48	17.5	275	213	47	18.1	260	91	24	20.9	115
HUD FHA	88	80	47.6	168	88	80	47.6	168	29	32	52.5	61
HUD PHA	5	2	28.6	7	5	2	28.6	7	3	2	40.0	5
HUD Grantee (High)*	190	12	5.9	202	188	12	6.0	200	143	12	7.7	155

Table 6-1b. Continued

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
HUD Grantee (Low)**	90	18	16.7	108	90	18	16.7	108	75	17	18.5	92
Atlantic City	14	3	17.6	17	14	3	17.6	17	8	3	27.3	11
Cleveland	2	0	0.0	2	2	0	0.0	2	2	0	0.0	2
All Components												
Maryland	581	95	14.1	676	347	75	17.8	422	132	36	21.4	168
HUD FHA	323	190	37.0	513	203	160	44.1	363	36	59	62.1	95
HUD PHA	55	15	21.4	70	45	11	19.6	56	30	5	14.3	35
HUD Grantee (High)*	1001	90	8.2	1091	795	85	9.7	880	420	68	13.9	488
HUD Grantee (Low)**	399	45	10.1	444	350	44	11.2	394	189	39	17.1	228
Atlantic City	43	16	27.1	59	31	15	32.6	46	13	7	35.0	20
Cleveland	18	3	14.3	21	18	3	14.3	21	11	3	21.4	14

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1c. Clearance Testing Results by Individual Sample, Room, and Housing Unit for the Third Site Visit.

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor												
Maryland	23	0	0.0	23	23	0	0.0	23	10	0	0.0	10
HUD FHA	46	34	42.5	80	43	32	42.7	75	19	16	45.7	35
HUD PHA	5	8	61.5	13	3	6	66.7	9	0	3	100.0	3
HUD Grantee (High)*	74	11	12.9	85	68	11	13.9	79	37	11	22.9	48
HUD Grantee (Low)**	30	3	9.1	33	30	3	9.1	33	23	3	11.5	26
Atlantic City	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
Cleveland	1	0	0.0	1	1	0	0.0	1	1	0	0.0	1
Window Sill												
Maryland	28	2	6.7	30	20	2	9.1	22	3	2	40.0	5
HUD FHA	17	21	55.3	38	17	21	55.3	38	10	11	52.4	21
HUD PHA	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
HUD Grantee (High)*	42	2	4.5	44	42	2	4.5	44	33	2	5.7	35
HUD Grantee (Low)**	18	0	0.0	18	18	0	0.0	18	15	0	0.0	15
Atlantic City	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
Cleveland	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
Window Trough												
Maryland	19	8	29.6	27	19	7	26.9	26	7	5	41.7	12
HUD FHA	35	47	57.3	82	35	45	56.3	80	12	18	60.0	30
HUD PHA	2	0	0.0	2	2	0	0.0	2	2	0	0.0	2
HUD Grantee (High)*	17	1	5.6	18	17	1	5.6	18	15	1	6.3	16

Table 6-1c. Continued

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
HUD Grantee (Low)**	19	4	17.4	23	19	4	17.4	23	18	4	18.2	22
Atlantic City	1	0	0.0	1	1	0	0.0	1	1	0	0.0	1
Cleveland	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
All Components												
Maryland	70	10	12.5	80	39	9	18.8	48	14	5	26.3	19
HUD FHA	98	102	51.0	200	71	87	55.1	158	21	34	61.8	55
HUD PHA	7	8	53.3	15	5	6	54.5	11	2	3	60.0	5
HUD Grantee (High)*	133	14	9.5	147	104	14	11.9	118	51	13	20.3	64
HUD Grantee (Low)**	67	7	9.5	74	64	7	9.9	71	45	7	13.5	52
Atlantic City	1	0	0.0	1	1	0	0.0	1	1	0	0.0	1
Cleveland	1	0	0.0	1	1	0	0.0	1	1	0	0.0	1

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1d. Clearance Testing Results by Individual Sample, Room, and Housing Unit for the Fourth Site Visit.

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor												
Maryland	3	0	0.0	3	3	0	0.0	3	1	0	0.0	1
HUD FHA	12	4	25.0	16	11	4	26.7	15	5	3	37.5	8
HUD PHA	8	0	0.0	8	6	0	0.0	6	3	0	0.0	3
HUD Grantee (High)*	10	0	0.0	10	9	0	0.0	9	9	0	0.0	9
HUD Grantee (Low)**	7	0	0.0	7	7	0	0.0	7	4	0	0.0	4
Window Sill												
Maryland	3	0	0.0	3	3	0	0.0	3	1	0	0.0	1
HUD FHA	5	7	58.3	12	5	7	58.3	12	1	2	66.7	3
HUD PHA	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
HUD Grantee (High)*	2	0	0.0	2	2	0	0.0	2	2	0	0.0	2
HUD Grantee (Low)**	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
Window Trough												
Maryland	4	1	20.0	5	4	1	20.0	5	2	1	33.3	3
HUD FHA	15	6	28.6	21	15	6	28.6	21	5	2	28.6	7
HUD PHA	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
HUD Grantee (High)*	2	0	0.0	2	2	0	0.0	2	2	0	0.0	2

Table 6-1d. Continued

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
HUD Grantee (Low)**	4	0	0.0	4	4	0	0.0	4	4	0	0.0	4
All Components												
Maryland	10	1	9.1	11	6	1	14.3	7	2	1	33.3	3
HUD FHA	32	17	34.7	49	23	11	32.4	34	7	4	36.4	11
HUD PHA	8	0	0.0	8	6	0	0.0	6	3	0	0.0	3
HUD Grantee (High)*	14	0	0.0	14	13	0	0.0	13	12	0	0.0	12
HUD Grantee (Low)**	11	0	0.0	11	11	0	0.0	11	8	0	0.0	8

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1e. Clearance Testing Results by Individual Sample, Room, and Housing Unit for the Fifth Site Visit.

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor												
HUD FHA	2	2	50.0	4	2	2	50.0	4	0	2	100.0	2
Window Sill												
HUD FHA	6	1	14.3	7	6	1	14.3	7	1	1	50.0	2
Window Trough												
HUD FHA	4	0	0.0	4	4	0	0.0	4	1	0	0.0	1
All Components												
HUD FHA	12	3	20.0	15	7	3	30.0	10	0	2	100.0	2

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1f. Clearance Testing Results by Individual Sample, Room, and Housing Unit for All Site Visits.

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor												
Maryland	2712	271	9.1	2983	2558	131	4.9	2689	592	70	10.6	662
HUD FHA	997	304	23.4	1301	910	61	6.3	971	129	16	11.0	145
HUD PHA	554	78	12.3	632	486	6	1.2	492	115	4	3.4	119
HUD Grantee (High)*	8345	537	6.0	8882	7652	470	5.8	8122	2054	48	2.3	2102
HUD Grantee (Low)**	3749	178	4.5	3927	3650	156	4.1	3806	1005	25	2.4	1030
Atlantic City	545	51	8.6	596	502	37	6.9	539	136	23	14.5	159
Cleveland	154	23	13.0	177	153	4	2.5	157	35	3	7.9	38
Dover	620	13	2.1	633	610	13	2.1	623	140	11	7.3	151
Window Sill												
Maryland	2411	281	10.4	2692	2243	166	6.9	2409	525	89	14.5	614
HUD FHA	689	147	17.6	836	674	21	3.0	695	119	14	10.5	133
HUD PHA	412	9	2.1	421	391	1	0.3	392	110	1	0.9	111
HUD Grantee (High)*	4906	219	4.3	5125	4683	199	4.1	4882	2004	38	1.9	2042
HUD Grantee (Low)**	2170	87	3.9	2257	2138	81	3.7	2219	951	22	2.3	973
Atlantic City	46	5	9.8	51	46	5	9.8	51	16	4	20.0	20
Cleveland	93	1	1.1	94	93	0	0.0	93	33	0	0.0	33
Dover	11	7	38.9	18	11	7	38.9	18	7	5	41.7	12

Table 6-1f. Continued

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Window Trough												
Maryland	1827	465	20.3	2292	1649	256	13.4	1905	434	107	19.8	541
HUD FHA	423	294	41.0	717	416	56	11.9	472	94	17	15.3	111
HUD PHA	371	9	2.4	380	356	0	0.0	356	110	0	0.0	110
HUD Grantee (High)*	3036	188	5.8	3224	2889	174	5.7	3063	1678	30	1.8	1708
HUD Grantee (Low)**	1341	140	9.5	1481	1333	124	8.5	1457	849	32	3.6	881
Atlantic City	267	9	3.3	276	260	6	2.3	266	118	4	3.3	122
Cleveland	39	2	4.9	41	39	0	0.0	39	24	0	0.0	24
Dover	260	5	1.9	265	256	5	1.9	261	141	5	3.4	146
All Components												
Maryland	6950	1017	12.8	7967	3077	425	12.1	3502	543	163	23.1	706
HUD FHA	2109	745	26.1	2854	961	125	11.5	1086	111	38	25.5	149
HUD PHA	1337	96	6.7	1433	814	7	0.9	821	115	4	3.4	119
HUD Grantee (High)*	16287	944	5.5	17231	10396	806	7.2	11202	2050	100	4.7	2150
HUD Grantee (Low)**	7260	405	5.3	7665	4595	341	6.9	4936	971	67	6.5	1038
Atlantic City	858	65	7.0	923	733	46	5.9	779	133	27	16.9	160
Cleveland	286	26	8.3	312	192	4	2.0	196	35	3	7.9	38
Dover	891	25	2.7	916	679	25	3.6	704	137	21	13.3	158

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1g. Clearance Testing Results for the Floor Samples at Various Clearance Standards for the First Site Visit

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Floor Standard at 40 $\mu g/ft^2$												
Maryland	1788	962	35.0	2750	1715	941	35.4	2656	285	376	56.9	661
HUD FHA	431	536	55.4	967	414	508	55.1	922	20	125	86.2	145
HUD PHA	238	320	57.3	558	209	281	57.3	490	15	104	87.4	119
HUD Grantee (High)*	6263	1916	23.4	8179	5715	1827	24.2	7542	1152	940	44.9	2092
HUD Grantee (Low)**	2936	706	19.4	3642	2875	689	19.3	3564	651	370	36.2	1021
Atlantic City	390	164	29.6	554	359	157	30.4	516	76	83	52.2	159
Cleveland	93	65	41.1	158	92	65	41.4	157	10	28	73.7	38
Dover	483	150	23.7	633	475	148	23.8	623	72	79	52.3	151
Floor Standard at 50 $\mu g/ft^2$												
Maryland	1909	841	30.6	2750	1831	825	31.1	2656	317	344	52.0	661
HUD FHA	491	476	49.2	967	470	452	49.0	922	28	117	80.7	145
HUD PHA	289	269	48.2	558	251	239	48.8	490	22	97	81.5	119
HUD Grantee (High)*	6596	1583	19.4	8179	6025	1517	20.1	7542	1275	817	39.1	2092
HUD Grantee (Low)**	3093	549	15.1	3642	3030	534	15.0	3564	723	298	29.2	1021
Atlantic City	424	130	23.5	554	388	128	24.8	516	87	72	45.3	159
Cleveland	104	54	34.2	158	103	54	34.4	157	12	26	68.4	38
Dover	528	105	16.6	633	519	104	16.7	623	89	62	41.1	151
Floor Standard at 100 $\mu g/ft^2$												
Maryland	2264	486	17.7	2750	2178	478	18.0	2656	429	232	35.1	661
HUD FHA	643	324	33.5	967	615	307	33.3	922	40	105	72.4	145
HUD PHA	425	133	23.8	558	376	114	23.3	490	55	64	53.8	119
HUD Grantee (High)*	7282	897	11.0	8179	6673	869	11.5	7542	1555	537	25.7	2092
HUD Grantee (Low)**	3351	291	8.0	3642	3279	285	8.0	3564	842	179	17.5	1021
Atlantic City	484	70	12.6	554	447	69	13.4	516	115	44	27.7	159
Cleveland	130	28	17.7	158	129	28	17.8	157	22	16	42.1	38
Dover	599	34	5.4	633	589	34	5.5	623	122	29	19.2	151

Table 6-1h. Clearance Testing Results for the Window Sill Samples at Various Clearance Standards for the First Site Visit

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Window Sill Standard at 125 $\mu g/ft^2$												
Maryland	1871	594	24.1	2465	1791	580	24.5	2371	328	284	46.4	612
HUD FHA	454	214	32.0	668	453	211	31.8	664	54	72	57.1	126
HUD PHA	351	60	14.6	411	336	55	14.1	391	67	44	39.6	111
HUD Grantee (High)*	4092	706	14.7	4798	3894	696	15.2	4590	1525	506	24.9	2031
HUD Grantee (Low)**	1809	338	15.7	2147	1789	334	15.7	2123	723	245	25.3	968
Atlantic City	40	11	21.6	51	40	11	21.6	51	12	8	40.0	20
Cleveland	74	19	20.4	93	74	19	20.4	93	21	12	36.4	33
Dover	1	17	94.4	18	1	17	94.4	18	1	11	91.7	12
Window Sill Standard at 250 $\mu g/ft^2$												
Maryland	2061	404	16.4	2465	1974	397	16.7	2371	405	207	33.8	612
HUD FHA	520	148	22.2	668	518	146	22.0	664	68	58	46.0	126
HUD PHA	384	27	6.6	411	367	24	6.1	391	89	22	19.8	111
HUD Grantee (High)*	4403	395	8.2	4798	4201	389	8.5	4590	1712	319	15.7	2031
HUD Grantee (Low)**	2006	141	6.6	2147	1983	140	6.6	2123	848	120	12.4	968
Atlantic City	43	8	15.7	51	43	8	15.7	51	13	7	35.0	20
Cleveland	88	5	5.4	93	88	5	5.4	93	28	5	15.2	33
Dover	3	15	83.3	18	3	15	83.3	18	2	10	83.3	12
Window Sill Standard at 500 $\mu g/ft^2$												
Maryland	2211	254	10.3	2465	2121	250	10.5	2371	470	142	23.2	612
HUD FHA	578	90	13.5	668	576	88	13.3	664	80	46	36.5	126
HUD PHA	402	9	2.2	411	383	8	2.0	391	103	8	7.2	111
HUD Grantee (High)*	4601	197	4.1	4798	4394	196	4.3	4590	1854	177	8.7	2031
HUD Grantee (Low)**	2068	79	3.7	2147	2044	79	3.7	2123	897	71	7.3	968
Atlantic City	46	5	9.8	51	46	5	9.8	51	16	4	20.0	20
Cleveland	92	1	1.1	93	92	1	1.1	93	32	1	3.0	33
Dover	11	7	38.9	18	11	7	38.9	18	7	5	41.7	12

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-1i. Clearance Testing Results for the Window Trough Samples at Various Clearance Standards for the First Site Visit

Data Source	Clearance Samples				Rooms Sampled				Houses Sampled			
	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total	Pass	Fail	%Failure	Total
Window Trough Standard at 400 $\mu g/ft^2$												
Maryland	1422	563	28.4	1985	1306	548	29.6	1854	284	252	47.0	536
HUD FHA	227	215	48.6	442	227	213	48.4	440	33	75	69.4	108
HUD PHA	361	10	2.7	371	346	10	2.8	356	103	7	6.4	110
HUD Grantee (High)*	2704	298	9.9	3002	2565	294	10.3	2859	1448	249	14.7	1697
HUD Grantee (Low)**	1141	205	15.2	1346	1134	205	15.3	1339	701	172	19.7	873
Atlantic City	243	15	5.8	258	239	15	5.9	254	106	13	10.9	119
Cleveland	34	5	12.8	39	34	5	12.8	39	20	4	16.7	24
Dover	257	8	3.0	265	253	8	3.1	261	138	8	5.5	146
Window Trough Standard at 800 $\mu g/ft^2$												
Maryland	1577	408	20.6	1985	1455	399	21.5	1854	337	199	37.1	536
HUD FHA	281	161	36.4	442	280	160	36.4	440	47	61	56.5	108
HUD PHA	364	7	1.9	371	349	7	2.0	356	105	5	4.5	110
HUD Grantee (High)*	2827	175	5.8	3002	2686	173	6.1	2859	1546	151	8.9	1697
HUD Grantee (Low)**	1228	118	8.8	1346	1221	118	8.8	1339	772	101	11.6	873
Atlantic City	252	6	2.3	258	248	6	2.4	254	114	5	4.2	119
Cleveland	37	2	5.1	39	37	2	5.1	39	22	2	8.3	24
Dover	260	5	1.9	265	256	5	1.9	261	141	5	3.4	146

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-2. Parameter Estimates and Associated Standard Errors from a Logistic Regression Model of the Probability of a Residential Unit Failing Clearance Testing Based on the Number of Samples Collected.

Data Source	Number of Residential Units	Parameter Estimates		Estimated Probability of Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is:		
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$n_i=2$	$n_i=4$	$n_i=6$
Floor						
Maryland	661	-2.0752 (0.2128)	0.1725† (0.0408)	0.15	0.20	0.26
HUD FHA	145	-0.8300 (0.4811)	0.1014 (0.0673)	0.35	0.40	0.44
HUD PHA	119	-1.8649 (0.5205)	0.1680 (0.0935)	0.18	0.23	0.30
HUD Grantee (High)*	2092	-2.2242 (0.1331)	0.1223† (0.0276)	0.12	0.15	0.18
HUD Grantee (Low)**	1021	-2.7460 (0.2728)	0.1753† (0.0655)	0.08	0.11	0.16
Atlantic City	159	-1.6335 (0.4505)	0.0719 (0.1122)	0.18	0.21	0.23
Cleveland	38	0.4396 (1.2155)	-0.2387 (0.2891)	0.49	0.37	0.27
Dover	151	-3.7027 (1.3086)	0.2692 (0.2872)	0.04	0.07	0.11
Window Sill						
Maryland	612	-1.1974 (0.2145)	0.0001 (0.0477)	0.23	0.23	0.23
HUD FHA	126	-1.5216 (0.4949)	0.1787† (0.0829)	0.24	0.31	0.39
HUD PHA	111	-2.2334 (0.9141)	-0.0892 (0.2381)	0.08	0.07	0.06
HUD Grantee (High)*	2031	-2.9473 (0.2002)	0.2431† (0.0718)	0.08	0.12	0.18
HUD Grantee (Low)**	968	-4.0901 (0.3921)	0.6520† (0.1471)	0.06	0.19	0.46
Atlantic City	20	-3.3278 (1.6858)	0.6941 (0.5227)	0.13	0.37	0.70
Cleveland	33	-3.8361 (2.7169)	0.1274 (0.8415)	0.03	0.03	0.04
Dover	12	-28.508 (0.8018)	27.2553† (0.0000)	1.00	1.00	1.00

Table 6-2. (Continued)

Data Source	Number of Residential Units	Parameter Estimates		Estimated Probability of Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is		
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$n_i = 2$	$n_i = 4$	$n_i = 6$
Window Trough						
Maryland	536	-0.9633 (0.1728)	0.1162† (0.0390)	0.32	0.38	0.43
HUD FHA	108	-0.9980 (0.5040)	0.3129† (0.1167)	0.41	0.56	0.71
HUD PHA	110	-3.7648 (1.2595)	0.2013† (0.3104)	0.03	0.05	0.07
HUD Grantee (High)*	1697	-2.3745 (0.1921)	0.0272 (0.0964)	0.09	0.09	0.10
HUD Grantee (Low)**	873	-2.8020 (0.2479)	0.4685† (0.1287)	0.13	0.28	0.50
Atlantic City	119	-4.0319 (1.3852)	0.3983 (0.5482)	0.04	0.08	0.16
Cleveland	24	-2.0794 (1.6104)	-0.2034 (0.9479)	0.08	0.05	0.04
Dover	146	-1.7713 (1.5213)	-0.9150 (0.9015)	0.03	< 0.01	< 0.01
All Components						
Maryland	706	-0.9567 (0.1630)	0.0658† (0.0139)	0.30	0.33	0.36
HUD FHA	149	-0.8188 (0.4109)	0.1093† (0.0295)	0.35	0.41	0.46
HUD PHA	119	-1.6193 (0.5009)	0.0741 (0.0383)	0.19	0.21	0.24
HUD Grantee (High)*	2132	-1.4488 (0.1276)	0.0431† (0.0152)	0.20	0.22	0.23
HUD Grantee (Low)**	1025	-1.7603 (0.2485)	0.0729† (0.0332)	0.17	0.19	0.21
Atlantic City	160	-1.9241 (0.5070)	0.1425 (0.0827)	0.16	0.21	0.26
Cleveland	38	0.1696 (1.0581)	-0.0788 (0.1334)	0.50	0.46	0.42
Dover	158	-1.5025 (0.8839)	-0.0649 (0.1498)	0.16	0.15	0.13

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

† Slope estimate is statistically significantly different from zero at the 0.05 level.

Table 6-3. **Categorization of the Number of Parameter Estimates and Associated Standard Errors from a Logistic Regression Model of the Probability of a Residential Unit Failing Clearance Testing Based on the Number of Samples Collected.**

Data Source	Number of Residential Units	Parameter Estimates		Estimated Probability of Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is Between	
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$1 \le n_i \le 4$	$5 \le n_i \le 8$
Floor					
Maryland	661	-2.2958 (0.2642)	0.6575† (0.1587)	0.16	0.27
HUD FHA	145	-1.1854 (0.5953)	0.4900 (0.2702)	0.33	0.45
HUD PHA	119	-1.6011 (0.5853)	0.3679 (0.3539)	0.23	0.30
HUD Grantee (High)*	2092	-2.4331 (0.1690)	0.4935† (0.1057)	0.13	0.19
HUD Grantee (Low)**	1021	-2.6618 (0.2904)	0.4377† (0.2042)	0.1	0.14
Atlantic City	159	-1.6540 (0.5459)	0.2144 (0.3911)	0.19	0.23
Cleveland	38	0.3245 (0.9610)	-0.6315 (0.6719)	0.42	0.28
Dover	151	-4.3550 (0.9710)	1.3932† (0.6457)	0.05	0.17
Window Sill					
Maryland	612	-0.8946 (0.2680)	-0.2257 (0.1893)	0.25	0.21
HUD FHA	126	-1.7193 (0.6237)	0.6634† (0.3337)	0.26	0.40
HUD PHA	111	-2.2893 (1.1202)	-0.2094 (0.8448)	0.08	0.06
HUD Grantee (High)*	2031	-3.3281 (0.3425)	0.9344† (0.3130)	0.08	0.19
HUD Grantee (Low)**	968	-4.4770 (0.8672)	1.9016† (0.8404)	0.07	0.34
Atlantic City	20	22.7218 (0.5627)	-24.044† (0.0000)	0.21	<0.01
Cleveland	33	20.6307 (1.0171)	-23.998† (0.0000)	0.03	<0.01
Dover	12	-0.3365 (0.5855)	0.0000 (0.0000)	0.42	0.42

Table 6-3. (Continued)

Data Source	Number of Residential Units	Parameter Estimates		Estimated Probability of Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is Between	
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$1 \leq n_i \leq 4$	$5 \leq n_i \leq 8$
Window Trough					
Maryland	536	-1.0503 (0.2259)	0.3923† (0.1546)	0.34	0.43
HUD FHA	108	-0.3354 (0.5799)	0.4150 (0.3825)	0.52	0.62
HUD PHA	110	-4.8865 (1.5555)	1.2755 (0.9376)	0.03	0.09
HUD Grantee (High)*	1697	-2.8219 (0.6447)	0.4880 (0.6272)	0.09	0.14
HUD Grantee (Low)**	873	-3.3893 (1.2431)	1.3481 (1.2293)	0.11	0.33
Atlantic City	119	18.1294 (0.4570)	-21.247 (0.0000)	0.04	<0.01
Cleveland	24	-2.3979 (0.7385)	0.0000 (0.0000)	0.08	0.08
Dover	146	-3.3393 (0.4551)	0.0000 (0.0000)	0.03	0.03
All Components					
Maryland	706	-1.1864 (0.2021)	0.3145† (0.0641)	0.29	0.36
HUD FHA	149	-0.8280 (0.4665)	0.4263† (0.1304)	0.40	0.51
HUD PHA	119	-1.5737 (0.5485)	0.2486 (0.1521)	0.21	0.25
HUD Grantee (High)*	2132	-1.4722 (0.1527)	0.1521† (0.0618)	0.21	0.24
HUD Grantee (Low)**	1025	-1.5823 (0.2778)	0.1561 (0.1232)	0.19	0.22
Atlantic City	160	-2.0008 (0.5285)	0.5086 (0.2818)	0.18	0.27
Cleveland	38	-0.0544 (1.1759)	-0.1529 (0.4638)	0.45	0.41
Dover	158	-1.2594 (1.3119)	-0.3203 (0.6757)	0.17	0.13

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.
† Slope estimate is statistically significantly different from zero at the 0.05 level.

Table 6-4. Parameter Estimates and Associated Standard Errors from a Logistic Regression Model of the Proportion of Samples within a Residential Unit Expected to Fail Clearance Testing Based on the Number of Samples Collected.

Data Source	Number of Residential Units	Parameter Estimates		Estimated Proportion of Samples Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is		
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$n_i = 2$	$n_i = 4$	$n_i = 6$
Floor						
Maryland	661	-2.2355 (0.1647)	-0.0133 (0.0282)	0.09	0.09	0.09
HUD FHA	145	-1.1178 (0.2601)	-0.0456 (0.0331)	0.23	0.21	0.20
HUD PHA	119	-2.4463 (0.4158)	0.0466 (0.0659)	0.09	0.09	0.10
HUD Grantee (High)*	2092	-2.5207 (0.1168)	-0.0572† (0.0222)	0.07	0.06	0.05
HUD Grantee (Low)**	1021	-2.9566 (0.2529)	-0.0360 (0.0579)	0.05	0.04	0.04
Atlantic City	159	-1.8520 (0.4094)	-0.1886 (0.0996)	0.10	0.07	0.05
Cleveland	38	-0.2857 (0.9032)	-0.3840 (0.2144)	0.26	0.14	0.07
Dover	151	-4.0533 (1.2004)	0.0425 (0.2617)	0.02	0.02	0.02
Window Sill						
Maryland	612	-1.2893 (0.1700)	-0.1854† (0.0353)	0.16	0.12	0.08
HUD FHA	126	-2.2012 (0.3326)	0.0529 (0.0477)	0.11	0.12	0.13
HUD PHA	111	-2.3940 (0.8824)	-0.3540 (0.2280)	0.04	0.02	0.01
HUD Grantee (High)*	2031	-2.9782 (0.1933)	-0.0635 (0.0668)	0.04	0.04	0.03
HUD Grantee (Low)**	968	-3.5886 (0.1592)	0.1141† (0.0348)	0.03	0.04	0.05
Atlantic City	20	-2.1174 (1.3324)	-0.0337 (0.4149)	0.10	0.10	0.09
Cleveland	33	-3.6164 (2.8720)	-0.2851 (0.8954)	0.01	0.01	< 0.01
Dover	12	-1.5343 (1.0379)	0.4964 (0.4056)	0.37	0.61	0.81

Table 6-4. Continued

Data Source	Number of Residential Units	Parameter Estimates		Estimated Proportion of Samples Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is		
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$n_i = 2$	$n_i = 4$	$n_i = 6$
Window Trough						
Maryland	536	-1.1680 (0.1059)	-0.0360† (0.0181)	0.22	0.21	0.20
HUD FHA	108	0.0062 (0.3009)	-0.1154† (0.0588)	0.44	0.39	0.33
HUD PHA	110	-4.1917 (1.2484)	0.0588 (0.2870)	0.02	0.02	0.02
HUD Grantee (High)*	1697	-2.2143 (0.1862)	-0.2745† (0.0865)	0.06	0.04	0.02
HUD Grantee (Low)**	873	-2.4714 (0.2308)	0.0679 (0.1093)	0.09	0.10	0.11
Atlantic City	119	-4.6205 (1.2611)	0.3490 (0.4482)	0.02	0.04	0.07
Cleveland	24	-1.5352 (1.6569)	-0.7794 (0.9769)	0.04	0.01	< 0.01
Dover	146	-1.0855 (1.5360)	-1.6073 (0.9097)	0.01	< 0.01	< 0.01
All Components						
Maryland	706	-1.6733 (0.0846)	-0.0197† (0.0060)	0.15	0.15	0.14
HUD FHA	149	-1.4924 (0.1596)	0.0091 (0.0086)	0.19	0.19	0.19
HUD PHA	119	-2.2296 (0.3438)	-0.0469 (0.0251)	0.09	0.08	0.08
HUD Grantee (High)*	2132	-2.4963 (0.1002)	-0.0457† (0.0111)	0.07	0.06	0.06
HUD Grantee (Low)**	1025	-3.1217 (0.1531)	0.0214 (0.0182)	0.04	0.05	0.05
Atlantic City	160	-2.5903 (0.4176)	-0.0356 (0.0641)	0.07	0.06	0.06
Cleveland	38	-1.1633 (0.7233)	-0.1595 (0.0896)	0.19	0.14	0.11
Dover	158	-1.1184 (0.8542)	-0.4140† (0.1467)	0.12	0.06	0.03

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

† Slope estimate is statistically significantly different from zero at the 0.05 level.

Table 6-5. Categorization of the Number of Parameter Estimates and Associated Standard Errors from a Logistic Regression Model of the Proportion of Samples within a Residential Unit Expected to Fail Clearance Testing Based on the Number of Samples Collected.

Data Source	Number of Residential Units	Parameter Estimates		Estimated Proportion of Samples Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is Between	
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$1 \le n_i \le 4$	$5 \le n_i \le 8$
Floor					
Maryland	661	-2.5154 (0.1925)	0.1205 (0.1032)	0.08	0.09
HUD FHA	145	-1.4789 (0.3043)	0.0074 (0.1261)	0.19	0.19
HUD PHA	119	-2.1458 (0.4304)	-0.0159 (0.2343)	0.10	0.10
HUD Grantee (High)*	2092	-2.5980 (0.1356)	-0.1256 (0.0792)	0.06	0.05
HUD Grantee (Low)**	1021	-3.0986 (0.2332)	-0.0058 (0.1563)	0.04	0.04
Atlantic City	159	-1.9776 (0.4594)	-0.4473 (0.3166)	0.08	0.05
Cleveland	38	-0.9233 (0.6693)	-0.6927 (0.4549)	0.17	0.09
Dover	151	-5.1085 (0.8678)	0.9188 (0.5639)	0.01	0.04
Window Sill					
Maryland	612	-1.1391 (0.1870)	-0.6903† (0.1251)	0.14	0.07
HUD FHA	126	-2.0246 (0.3982)	0.0835 (0.1923)	0.13	0.13
HUD PHA	111	-2.3408 (1.0466)	-1.0932 (0.8080)	0.03	0.01
HUD Grantee (High)*	2031	-3.3402 (0.2779)	0.1747 (0.2459)	0.04	0.05
HUD Grantee (Low)**	968	-3.7198 (0.2141)	0.4153† (0.1562)	0.04	0.05
Atlantic City	20	21.7156 (0.4737)	-23.820† (0.0000)	0.11	<0.01
Cleveland	33	19.2362 (1.0065)	-23.580† (0.0000)	0.01	<0.01
Dover	12	-0.4520 (0.4835)	0.0000 (0.0000)	0.39	0.39

Table 6-5. Continued

Data Source	Number of Residential Units	Parameter Estimates		Estimated Proportion of Samples Failing Clearance Testing When the Number of Samples Collected Within a Residential Unit is Between	
		β_0 s.e. (β_0)	β_1 s.e. (β_1)	$1 \le n_i \le 4$	$5 \le n_i \le 8$
Window Trough					
Maryland	536	-1.2361 (0.1244)	-0.0708 (0.0686)	0.21	0.2
HUD FHA	108	0.2344 (0.3207)	-0.4885† (0.1902)	0.44	0.32
HUD PHA	110	-5.6392 (1.4921)	1.0594 (0.8432)	0.01	0.03
HUD Grantee (High)*	1697	-2.7639 (0.4205)	-0.0175 (0.3973)	0.06	0.06
HUD Grantee (Low)**	873	-2.0399 (1.0530)	-0.2996 (1.0396)	0.09	0.07
Atlantic City	119	18.4886 (0.4132)	-22.206† (0.0000)	0.02	<0.01
Cleveland	24	-2.9178 (0.7260)	0.0000 (0.0000)	0.05	0.05
Dover	146	-3.9512 (0.4515)	0.0000 (0.0000)	0.02	0.02
All Components					
Maryland	706	-1.8066 (0.1128)	-0.0360 (0.0309)	0.14	0.13
HUD FHA	149	-1.1257 (0.2019)	-0.0505 (0.0474)	0.24	0.23
HUD PHA	119	-2.0704 (0.3687)	-0.2130† (0.0985)	0.09	0.08
HUD Grantee (High)*	2132	-2.3494 (0.1173)	-0.2129† (0.0450)	0.07	0.06
HUD Grantee (Low)**	1025	-2.7902 (0.2156)	-0.0719 (0.0912)	0.05	0.05
Atlantic City	160	-2.7647 (0.4212)	-0.0241 (0.2101)	0.06	0.06
Cleveland	38	-1.2386 (0.8123)	-0.4689 (0.3130)	0.15	0.10
Dover	158	-0.3746 (1.1666)	-1.6367† (0.6075)	0.12	0.03

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

† Slope estimate is statistically significantly different from zero at the 0.05 level.

6.2 OBJECTIVE 2: CHARACTERIZATION OF THE DISTRIBUTION OF THE DUST-LEAD LOADINGS, GEOMETRIC MEAN DUST-LEAD LOADINGS, VARIABILITY BETWEEN SAMPLES COLLECTED WITHIN HOUSING UNITS, AND VARIABILITY ACROSS HOUSING UNITS

The geometric mean, the house-to-house variability ($\sigma_{Between}$), and the room-to-room variability within a home (σ_{Within}) by site visit and component tested are listed in Tables 6-6a to 6-6d, for the first site visit to fourth site visit, respectively. In addition, these tables also present the lower and upper 95% confidence bounds for the geometric mean and the 95% prediction bounds which were calculated using the two sources of variability, $\sigma_{Between}$ and σ_{Within}. Section 5.2 discusses the equations used to estimate $\sigma_{Between}$ and σ_{Within} from the ln-transformed data. Note that the length of the confidence intervals for any given component type increases successively from the first to the fourth site visit. This increase in length is due primarily to the decrease by orders of magnitude in the sample size used to estimate the variance components.

Generally, for a given component type, geometric means of the samples collected increase from the first to the third site visit, then decrease from the third to the fourth site visit. In the first site visit, Table 6-6a shows that geometric mean floor, window sill, and window trough dust-lead loadings range from 8.8 to 57.6 $\mu g/ft^2$, 11.3 to 461.6 $\mu g/ft^2$, and 15.8 to 393.3 $\mu g/ft^2$, respectively. While the HUD Grantee High data group presents the lowest geometric mean floor and window sill dust-lead loadings at 8.8 and 11.3 $\mu g/ft^2$ across eight data sources, the HUD FHA data group presents the highest geometric mean floor and window trough dust-lead loadings at 57.6 and 393.3 $\mu g/ft^2$.

The Dover data group presents the highest geometric mean window sill dust-lead loadings and the lowest geometric mean window trough dust-lead loadings. This may be attributed to the interior renovation strategy used by Dover Housing Authority, which consisted of removing lead painted radiators generally located under a window and window replacement. Window replacement may not necessarily include replacing window sills.

The percentages of dust-lead clearance samples below 50, 75, 100 $\mu g/ft^2$ and the applicable interim clearance standard (200 $\mu g/ft^2$ for floor, 500 $\mu g/ft^2$ for window sill, and 800 $\mu g/ft^2$ for window trough) by component type and substrate are presented in Tables 6-7a (first site visit) to 6-7d (fourth site visit) and 6-8 (passed clearance visits). The 50th, 80th, 90th, 95th, and 99th percentiles for the dust-lead clearance samples for the first site visit and the passed clearance visits and combinations of data source and substrate are presented in Tables 6-9a to 6-9c and 6-10a to 6-10c. Additional tables listing the percentiles by data source are provided in

Appendix I. Box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type and substrate are displayed in the appendices for each individual data source.

Using the results in Tables 6-6 through 6-10, Tables I-1 through I-4 and Figures I-1 to I-18 in Appendix I, and the box and whisker plots displayed in Appendices A to G, the following comparisons were made:

What lead levels for floors, window sills, or window troughs are typical in dust clearance testing?

Table 6-6a shows that the geometric mean dust-lead loading from floors ranged from 8.8 to 57.6 µg/ft² with an upper 95% prediction bound ranging from 68 to 509 µg/ft² for the first site visit. Although the geometric mean lead loading for floors was significantly less than the 200 µg/ft² clearance standard, some of the 95% upper prediction bounds were above the 200 µg/ft² level. Similar results were obtained for window sills and troughs. The geometric mean lead loading for window sills ranged from 11.3 to 461.6 µg/ft² with a 95% upper prediction bound ranging from 89 to 7559 µg/ft² for the first site visit compared to the 500 µg/ft² clearance standard. The geometric mean lead loading for window troughs was between 15.8 and 393.3 µg/ft², and the upper 95% prediction bound was between 137 and 4119 µg/ft² for the first site visit compared to the 800 µg/ft² clearance standard.

Another way to answer the question is to consider the percentiles of the dust wipe sample results presented in Tables 6-9a to 6-9c and 6-10a to 6-10c, and Tables I-1 through I-4 in Appendix I. These results indicate that for the first site visit between 90 and 95% of the floor dust wipe sample results and 80 to 90% of the window sill and window trough clearance samples were below the Interim EPA/HUD clearance standards. However, as seen in Tables 6-9a to 6-9c, there are some extremely high values associated with the 95th and 99th percentiles. Most of these extreme values are from the Maryland and the FHA HUD Demonstration data. Both sets of results were obtained after the housing units had passed a visual inspection. The FHA dust wipe samples were obtained before a sealant was applied to the sampled surface, while the Maryland data were obtained by following the HUD Interim Guidelines Clearance Standards [2]: applying a sealant to the designated surfaces and then performing clearance sampling.

A data set was constructed which included lead loading results only from housing units that passed lead clearance (passed clearance data set). An analysis of the distribution of dust

wipe clearance sample results for this data set would indicate the levels attained for all the housing units that passed the clearance standards. As shown in Tables 6-10a, when considering the category of all substrates, the 80th, 90th, and 95th percentile lead levels for bare floor dust wipe samples ranged from 34 to 102 µg/ft², from 57 to 141 µg/ft², and from 82 to 165 µg/ft², respectively. For all substrates in window sills (Table 6-10b), the 80th, 90th, and 95th percentiles ranged from 72 to 443 µg/ft², from 141 to 443 µg/ft², and from 215 to 467 µg/ft², respectively, and from 59 to 431 µg/ft², from 111 to 598 µg/ft², and from 157 to 678 µg/ft² for all substrates in window troughs (Table 6-10c), respectively.

For each site visit, how do the dust-lead levels compare across component type?

Tables 6-6a to 6-6d show that for all site visits, generally for most of the data sources, the geometric mean dust-lead loading for floors was less than the mean for window sills. In turn, the geometric mean dust-lead loading for window sills was less than the mean for window troughs. One obvious exception is Dover's window sill and trough data.

For each component, how do the dust-lead levels compare across site visits?

As shown in Tables 6-6a to 6-6c, for each component type, the geometric mean lead-loading increased from the first to the second site visit, and then again from the second to the third site visit. This trend may be due to the fact that typically only those homes which did not pass clearance standards on the previous site visit were included in the subsequent site visit (i.e., only the dirtiest homes were included).

What are the problem areas in terms of cleaning? Is one area more difficult to clean than another?

As shown in Table 6-6a, the geometric mean dust-lead loading ranged 8.8 to 57.6 µg/ft² for floors, 11.3 to 461.6 µg/ft² for window sills, and 15.8 to 393.3 µg/ft² for window troughs for the first site visit. The geometric mean lead loading for floors, window sills, and window troughs increased from the first site visit to the second site visit, and then again from the second site visit to the third site visit. The geometric means decreased from the third site visit to the fourth site visit, but there are very few samples to estimate the geometric mean during the fourth site visit. The window trough results were higher than the window sill or floor results, except for during the fourth site visit. This was determined using a comparison of the 95% confidence

intervals constructed from the variance component models (the level of significance is actually less than 5% for the comparison).

The higher dust wipe sample results for window troughs were discussed with experts in the field. They collectively indicated that window troughs are the most difficult of the three surfaces to pass clearance. Many of them indicated that contractors will first, if possible, replace old windows with either vinyl or aluminum windows, and second, put a laminated aluminum coil or insert over an enclosure. Their third option is to refinish the window trough using more involved on-site paint removal techniques. However, this third option is less desirable because it creates leaded debris, and there is an experience factor required to do the job adequately.

Can window sills be cleaned to the same levels as floors?

Note that the available data were not designed to answer this question directly. The data can provide insights however.

Table 6-6a shows that for some data sources (e.g., HUD FHA, HUD Grantee High, and Cleveland), the 95% confidence intervals for geometric mean dust-lead loading from floors and from window sills overlap. The 95% confidence interval for geometric mean dust-lead loading from window sills is even lower than that from floors for the HUD PHA data. (Note that the level of significance is actually less than 5% for the comparison.)

Table 6-7a shows that for the first site visit at the 50, 75, and 100 $\mu g/ft^2$ standard levels, over all substrates, the percentage of floor-lead loading results below the standard exceeds the percentage of window sill results below the standard by approximately 10%.

As seen in Tables 6-9a, 6-9b, 6-10a, and 6-10b, and Tables I-1 through I-4 in Appendix I, at each percentile (50th, 80th, 90th, 95th, and 99th) the floor dust-lead loadings are generally lower than the corresponding window sill dust-lead loadings. This indicates that floors were generally cleaned to a lower level (i.e., cleaner, or less lead dust remaining) than window sills.

Can window troughs be cleaned to the same levels as window sills?

Again, as stated above, while the available data in this report were not designed to answer this question directly, the data can provide insights.

Table 6-6a shows that the geometric mean dust-lead loading from window sills ranged from 11.3 to 461.6 $\mu g/ft^2$ for the first site visit. The geometric mean lead loading for window troughs ranged 15.8 to 393.3 $\mu g/ft^2$ for the first site visit. Their lower and upper 95% confidence

bounds do overlap for some data sources. (Note that the level of significance is actually less than 5% for the comparison.)

Tables 6-7a to 6-7d and 6-8 show that a greater proportion of window sill dust-lead loadings fell below the standards of 50, 75, and 100 μg/ft^2 than the window trough dust-lead loadings for most of the larger data sources (specifically, Maryland, HUD FHA, HUD Grantee High and Low). Assessing the first site visit at the interim clearance standards of 50, 75, and 100 μg/ft^2, approximately 10% more of the window sill dust-lead loadings were below each standard than the associated window trough dust-lead loadings for those larger data sources. As seen in Tables 6-9b, 6-9c, 6-10b, and 6-10c, and Tables I-1 through I-4 in Appendix I, at each percentile (50th, 80th, 90th, 95th, and 99th) the window sill dust-lead loadings are generally lower than the corresponding window trough dust-lead loadings. This indicates that window sills were generally cleaned to a lower level (i.e., cleaner, or less lead dust remaining) than window troughs.

How do the distributions of floor, window sill, and window trough lead loadings compare for first site and passed clearance site visits?

The first set of box and whisker plots that are presented in the appendices for each individual data source display the distributions of dust lead loadings from the first and passed clearance site visits for floors, window sills, and window troughs on a log scale. These results clearly indicate that the distribution of dust-lead loadings for each component type during the first site visit and passed clearance site visits are significantly skewed and variable. The distributions of dust-lead loading results from the "passed clearance" data for floors, window sills, and window troughs are displayed on an untransformed scale in the second set of box and whisker plots in the appendices for each individual data source. The skewness of the distributions of dust-lead loading results for window sills and window troughs for the passed clearance site visit data are better displayed on the original lead loading, μg/ft^2, scale. In both figures, the floor dust wipe sample results are generally lower than sample results for the window sills, which are lower than window trough sample results.

Table 6-6a. Geometric Mean and Variance Component Estimates by Component Type and Data Source for the First Site Visit

Data Source	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	Lower 95% Confidence Bound	Upper 95% Confidence Bound	Lower 95% Prediction Bound	Upper 95% Prediction Bound
Floor										
Maryland	2750	2656	661	22.4	1.18	0.95	20	25	3	176
HUD FHA	967	922	145	57.6	1.15	1.05	47	71	7	509
HUD PHA	558	490	119	52.9	0.65	0.70	46	61	6	438
HUD Grantee (High)*	8179	7542	2092	8.8	1.73	1.73	8	10	1	68
HUD Grantee (Low)	3642	3564	1021	12.3	1.44	1.13	11	14	2	96
Atlantic City	554	516	159	18.5	0.84	1.00	16	22	2	156
Cleveland	158	157	38	29.7	0.67	1.05	22	39	3	298
Dover	633	623	151	13.5	0.74	1.02	12	16	2	112
Window Sill										
Maryland	2465	2371	612	41.7	1.50	1.14	37	47	5	338
HUD FHA	668	664	126	60.3	1.46	1.32	46	80	6	577
HUD PHA	411	391	111	32.7	0.73	0.95	28	39	4	281
HUD Grantee (High)*	4798	4590	2031	11.3	2.03	1.84	10	13	1	89
HUD Grantee (Low)	2147	2123	968	24.9	1.49	1.55	22	28	3	199
Atlantic City	51	51	20	43.1	0.88	1.29	24	76	3	619
Cleveland	93	93	33	37.8	0.81	0.86	27	54	3	411
Dover	18	18	12	461.6	0.00	1.15	255	837	28	7559
Window Trough										
Maryland	1985	1854	536	144.2	1.84	1.37	122	171	17	1220
HUD FHA	442	440	108	393.3	1.78	1.27	273	567	38	4119
HUD PHA	371	356	110	43.5	0.66	0.73	37	50	5	366
HUD Grantee (High)*	3002	2859	1697	26.5	1.92	1.65	24	30	3	211
HUD Grantee (Low)	1346	1339	873	66.5	1.59	1.39	58	76	8	540
Atlantic City	258	254	119	19.4	0.93	1.19	15	24	2	176
Cleveland	39	39	24	44.7	1.45	1.00	22	91	3	719
Dover	265	261	146	15.8	0.63	1.26	13	19	2	137

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-6b. Geometric Mean and Variance Component Estimates by Component Type and Data Source for the Second Site Visit

Data Source	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	Lower 95% Confidence Bound	Upper 95% Confidence Bound	Lower 95% Prediction Bound	Upper 95% Prediction Bound
Floor										
Maryland	207	200	97	28.7	1.03	1.07	22	37	3	273
HUD FHA	234	219	70	99.9	1.22	1.09	71	140	10	1026
HUD PHA	53	43	27	50.1	1.00	0.75	31	80	4	623
HUD Grantee (High)*	608	560	333	17.6	1.40	1.53	14	22	2	154
HUD Grantee** (Low)	245	235	147	13.8	1.45	1.26	10	19	1	134
Atlantic City	42	37	16	42.0	1.17	0.96	20	89	2	753
Cleveland	18	18	13	29.4	1.29	0.38	13	66	1	581
Window Sill										
Maryland	194	187	78	55.5	1.65	0.92	37	83	5	609
HUD FHA	111	108	51	171.9	1.30	1.53	105	281	14	2097
HUD PHA	10	10	9	24.8	1.28	0.43	9	69	1	693
HUD Grantee (High)*	281	275	209	33.7	1.48	1.76	25	45	3	326
HUD Grantee** (Low)	91	90	74	30.5	2.33	1.05	17	55	2	402
Cleveland	1	1	1	1.0	0.00	0.00	.	.	.	.
Window Trough										
Maryland	275	260	115	114.0	1.47	1.15	83	156	11	1132
HUD FHA	168	168	61	562.8	1.39	1.37	368	860	50	6360
HUD PHA	7	7	5	122.3	0.80	1.31	22	680	1	10925
HUD Grantee (High)*	202	200	155	45.6	1.89	1.28	32	65	4	468
HUD Grantee** (Low)	108	108	92	99.0	1.28	1.85	63	155	9	1130
Atlantic City	17	17	11	58.6	2.02	1.38	12	286	1	2659
Cleveland	2	2	2	402.5	0.16	0.38	10	16847	0	5556028525

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-6c. Geometric Mean and Variance Component Estimates by Component Type and Data Source for the Third Site Visit

Data Source	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	Lower 95% Confidence Bound	Upper 95% Confidence Bound	Lower 95% Prediction Bound	Upper 95% Prediction Bound
Floor										
Maryland	23	23	10	30.6	0.86	0.66	15	62	2	600
HUD FHA	80	75	35	168.4	0.85	1.04	114	249	15	1901
HUD PHA	13	9	3	213.4	0.73	0.58	30	1515	0	111928
HUD Grantee (High)*	85	79	48	29.0	0.89	1.88	18	48	2	356
HUD Grantee (Low)	33	33	26	19.7	1.52	1.39	9	44	1	344
Cleveland	1	1	1	1.0	0.00	0.00	.	.	.	.
Window Sill										
Maryland	30	22	5	45.2	1.64	0.85	6	366	0	5883
HUD FHA	38	38	21	580.8	1.46	1.09	265	1272	33	10242
HUD Grantee (High)*	44	44	35	50.2	0.94	1.32	30	85	4	647
HUD Grantee (Low)	18	18	15	38.6	2.22	0.51	11	135	1	1156
Window Trough										
Maryland	27	26	12	192.5	1.32	1.28	67	554	7	5006
HUD FHA	82	80	30	643.7	1.28	1.08	370	1120	48	8659
HUD PHA	2	2	2	66.9	0.00	0.69	0	33335	0	1.09935E10
HUD Grantee (High)*	18	18	16	87.8	0.00	1.14	50	156	6	1311
HUD Grantee (Low)	23	23	22	97.1	2.06	1.90	28	334	4	2673
Atlantic City	1	1	1	1.0	0.00	0.00	.	.	.	.

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-6d. Geometric Mean and Variance Component Estimates by Component Type and Data Source for the Fourth Site Visit

Data Source	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean	$\sigma_{Between}$ ln (µg/ft²)	σ_{Within} ln (µg/ft²)	Lower 95% Confidence Bound	Upper 95% Confidence Bound	Lower 95% Prediction Bound	Upper 95% Prediction Bound
Floor										
Maryland	3	3	1	44.6	0.00	1.14	.	.	.	.
HUD FHA	16	15	8	56.1	0.98	1.22	18	170	2	1812
HUD PHA	8	6	3	69.5	0.00	0.58	29	169	0	12468
HUD Grantee (High)*	10	9	9	13.8	1.00	0.43	6	32	1	318
HUD Grantee (Low)	7	7	4	11.3	1.16	0.58	1	85	0	2054
Window Sill										
Maryland	3	3	1	111.6	0	1.25	.	.	.	.
HUD FHA	12	12	3	437.8	0.78	0.45	56	3398	1	251066
HUD Grantee (High)*	2	2	2	115.3	0.00	0.20	19	706	0	232810507
Window Trough										
Maryland	5	5	3	367.5	0.29	0.52	103	1313	1	96992
HUD FHA	21	21	7	144.4	2.21	0.98	17	1228	1	14185
HUD Grantee (High)*	2	2	2	54.3	0.29	0.50	0	10148	0	3346562914
HUD Grantee (Low)	4	4	4	130.1	0.11	0.00	109	155	5	3730

* Grantees that used 200 µg/ft² as clearance standard for floor.
** Grantees that used 100 µg/ft² or 80 µg/ft² as clearance standard for floor.

Table 6-7a. Percentage of Clearance Samples Below 50 $\mu g/ft^2$, 75 $\mu g/ft^2$, 100 $\mu g/ft^2$, and HUD Interim Guidance Clearance Standards by Data Source and Substrate for the First Site Visit.

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Floor						
Maryland	All	2750	69	77	82	91
	Wood	1082	71	79	84	91
	Vinyl	660	68	75	80	90
	Other	19	37	42	68	84
	Unknown	989	70	78	82	91
HUD FHA	All	967	51	61	66	81
	Unknown	967	51	61	66	81
HUD PHA	All	558	52	66	76	90
	Unknown	558	52	66	76	90
HUD Grantee (High)*	All	8179	81	86	89	94
	Wood	2027	75	82	85	92
	Vinyl	4067	83	89	91	95
	Other	2076	81	86	89	95
	Unknown	9	89	89	100	100
HUD Grantee (Low)**	All	3642	85	90	92	96
	Wood	1774	86	92	93	97
	Vinyl	1510	87	91	93	96
	Other	358	70	78	81	91
Atlantic City	All	554	77	84	87	93
	Unknown	554	77	84	87	93
Cleveland	All	158	66	77	82	87
	Unknown	158	66	77	82	87
Dover	All	633	83	91	95	98
	Wood	3	67	100	100	100
	Vinyl	625	84	91	95	98
	Unknown	5	80	80	100	100

Table 6-7a. Continued

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Window Sill						
Maryland	All	2465	60	68	72	90
	Wood	1687	62	70	74	92
	Vinyl	97	81	88	90	97
	Aluminum	40	73	75	83	98
	Other	18	78	83	83	100
	Unknown	623	51	58	63	82
HUD FHA	All	668	48	59	64	87
	Unknown	668	48	59	64	87
HUD PHA	All	411	66	79	83	98
	Unknown	411	66	79	83	98
HUD Grantee (High)*	All	4798	71	78	82	96
	Wood	636	56	65	72	92
	Vinyl	37	78	81	84	92
	Other	4120	73	80	84	97
	Unknown	5	60	60	60	80
HUD Grantee (Low)**	All	2147	57	68	78	96
	Wood	507	49	62	71	96
	Vinyl	35	71	74	77	94
	Other	1605	59	70	80	97
Atlantic City	All	51	57	65	75	90
	Unknown	51	57	65	75	90
Cleveland	All	93	61	69	78	99
	Unknown	93	61	69	78	99
Dover	All	18	6	6	6	61
	Wood	9	0	0	0	44
	Vinyl	1	0	0	0	100
	Aluminum	4	25	25	25	100
	Unknown	4	0	0	0	50

Table 6-7a. Continued

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Window Trough						
Maryland	All	1985	41	47	51	79
	Wood	458	27	32	36	67
	Vinyl	551	54	60	65	92
	Aluminum	286	50	57	62	88
	Unknown	690	36	42	46	74
HUD FHA	All	442	17	22	25	64
	Unknown	442	17	22	25	64
HUD PHA	All	371	58	75	82	98
	Unknown	371	58	75	82	98
HUD Grantee (High)*	All	3002	61	68	73	94
	Wood	34	47	59	65	94
	Vinyl	1626	69	76	81	97
	Other	1341	51	59	65	91
	Unknown	1	0	0	0	0
HUD Grantee (Low)**	All	1346	36	48	56	91
	Wood	65	32	37	40	78
	Vinyl	238	69	75	79	94
	Other	1043	29	42	52	91
Atlantic City	All	258	75	81	84	98
	Unknown	258	75	81	84	98
Cleveland	All	39	64	67	72	95
	Unknown	39	64	67	72	95
Dover	All	265	77	83	88	98
	Vinyl	185	74	79	85	97
	Aluminum	11	91	91	91	100
	Other	2	50	50	50	100
	Unknown	67	85	94	96	100

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-7b. Percentage of Clearance Samples Below 50 $\mu g/ft^2$, 75 $\mu g/ft^2$, 100 $\mu g/ft^2$, and HUD Interim Guidance Clearance Standards by Data Source and Substrate for the Second Site Visit.

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Floor						
Maryland	All	207	59	69	76	89
	Wood	71	56	65	75	85
	Vinyl	52	50	62	67	88
	Other	3	33	33	67	100
	Unknown	81	69	79	84	94
HUD FHA	All	234	31	38	46	65
	Unknown	234	31	38	46	65
HUD PHA	All	53	36	45	57	75
	Unknown	53	36	45	57	75
HUD Grantee (High)*	All	608	69	77	82	90
	Unknown	608	69	77	82	90
HUD Grantee (Low)**	All	245	76	82	86	92
	Unknown	245	76	82	86	92
Atlantic City	All	42	33	40	40	69
	Unknown	42	33	40	40	69
Cleveland	All	18	61	72	72	83
	Unknown	18	61	72	72	83
Window Sill						
Maryland	All	194	52	59	65	87
	Wood	102	46	52	58	80
	Vinyl	12	92	92	92	100
	Aluminum	3	67	100	100	100
	Unknown	77	53	62	69	94
HUD FHA	All	111	26	33	40	75
	Unknown	111	26	33	40	75
HUD PHA	All	10	80	80	90	100
	Unknown	10	80	80	90	100

Table 6-7b. Continued

Data Source	Substrate	Sample Size	Percentage of Samples Below 50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Window Sill						
HUD Grantee (High)*	All	281	54	63	68	93
	Unknown	281	54	63	68	93
HUD Grantee (Low)**	All	91	57	64	66	91
	Unknown	91	57	64	66	91
Cleveland	All	1	100	100	100	100
	Unknown	1	100	100	100	100
Window Trough						
Maryland	All	275	35	44	49	83
	Wood	83	20	34	36	73
	Vinyl	72	47	56	63	93
	Aluminum	30	47	53	67	97
	Unknown	90	34	40	43	78
HUD FHA	All	168	10	14	15	52
	Unknown	168	10	14	15	52
HUD PHA	All	7	29	57	71	71
	Unknown	7	29	57	71	71
HUD Grantee (High)*	All	202	48	58	63	94
	Unknown	202	48	58	63	94
HUD Grantee (Low)**	All	108	35	44	50	83
	Unknown	108	35	44	50	83
Atlantic City	All	17	47	59	59	82
	Unknown	17	47	59	59	82

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-7c. Percentage of Clearance Samples Below 50 $\mu g/ft^2$, 75 $\mu g/ft^2$, 100 $\mu g/ft^2$, and HUD Interim Guidance Clearance Standards by Data Source and Substrate for the Third Site Visit.

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Floor						
Maryland	All	23	74	83	87	100
	Wood	2	100	100	100	100
	Vinyl	11	55	73	82	100
	Other	1	100	100	100	100
	Unknown	9	89	89	89	100
HUD FHA	All	80	6	21	34	58
	Unknown	80	6	21	34	58
HUD PHA	All	13	8	8	8	38
	Unknown	13	8	8	8	38
HUD Grantee (High)*	All	85	54	71	73	87
	Unknown	85	54	71	73	87
HUD Grantee (Low)**	All	33	64	73	82	91
	Unknown	33	64	73	82	91
Cleveland	All	1	100	100	100	100
	Unknown	1	100	100	100	100
Window Sill						
Maryland	All	30	73	77	77	93
	Wood	18	78	78	78	94
	Aluminum	3	33	33	33	67
	Unknown	9	78	89	89	100
HUD FHA	All	38	8	13	18	45
	Unknown	38	8	13	18	45
HUD Grantee (High)*	All	44	36	45	57	95
	Unknown	44	36	45	57	95
HUD Grantee (Low)**	All	18	44	50	56	100

Table 6-7c. Continued

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Window Trough						
Maryland	All	27	30	33	37	70
	Wood	8	0	0	0	50
	Vinyl	3	33	67	100	100
	Aluminum	3	0	0	0	33
	Unknown	13	54	54	54	85
HUD FHA	All	82	10	13	17	43
	Unknown	82	10	13	17	43
HUD PHA	All	2	50	50	50	100
	Unknown	2	50	50	50	100
HUD Grantee (High)*	All	18	33	44	56	94
	Unknown	18	33	44	56	94
HUD Grantee (Low)**	All	23	35	39	39	83
	Unknown	23	35	39	39	83
Atlantic City	All	1	100	100	100	100
	Unknown	1	100	100	100	100

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-7d. Percentage of Clearance Samples Below 50 $\mu g/ft^2$, 75 $\mu g/ft^2$, 100 $\mu g/ft^2$, and HUD Interim Guidance Clearance Standards by Data Source and Substrate for the Fourth Site Visit.

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Floor						
Maryland	All	3	33	33	100	100
	Unknown	3	33	33	100	100
HUD FHA	All	16	44	63	63	75
	Unknown	16	44	63	63	75
HUD PHA	All	8	25	63	75	100
	Unknown	8	25	63	75	100
HUD Grantee (High)*	All	10	90	100	100	100
	Unknown	10	90	100	100	100
HUD Grantee (Low)**	All	7	100	100	100	100
	Unknown	7	100	100	100	100
Window Sill						
Maryland	All	3	33	33	67	100
	Unknown	3	33	33	67	100
HUD FHA	All	12	0	0	0	42
	Unknown	12	0	0	0	42
HUD Grantee (High)*	All	2	0	0	0	100
	Unknown	2	0	0	0	100
Window Trough						
Maryland	All	5	0	0	0	80
	Wood	1	0	0	0	100
	Unknown	4	0	0	0	75
HUD FHA	All	21	10	24	29	71
	Unknown	21	10	24	29	71
HUD Grantee (High)*	All	2	50	50	100	100
	Unknown	2	50	50	100	100
HUD Grantee (Low)**	All	4	0	0	0	100
	Unknown	4	0	0	0	100

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-8. Percentage of Clearance Samples Below 50 $\mu g/ft^2$, 75 $\mu g/ft^2$, 100 $\mu g/ft^2$, and HUD Interim Guidance Clearance Standards by Data Source and Substrate for the Passed Clearance Visits.

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Floor						
Maryland	All	2712	76	85	90	100
	Wood	1052	77	86	92	100
	Vinyl	651	74	82	88	100
	Other	20	45	50	80	100
	Unknown	989	76	85	90	100
HUD FHA	All	997	58	71	79	100
	Unknown	997	58	71	79	100
HUD PHA	All	554	56	72	83	100
	Unknown	554	56	72	83	100
HUD Grantee (High)*	All	8345	85	91	94	100
	Wood	1859	82	90	93	100
	Vinyl	3875	87	93	96	100
	Other	1968	85	90	94	100
	Unknown	643	75	85	90	100
HUD Grantee (Low)**	All	3749	88	93	96	100
	Wood	1716	89	95	97	100
	Vinyl	1446	91	95	97	100
	Other	324	77	86	90	100
	Unknown	263	82	88	93	100
Atlantic City	All	545	80	89	92	100
	Unknown	545	80	89	92	100
Cleveland	All	154	75	88	94	100
	Unknown	154	75	88	94	100
Dover	All	620	85	93	97	100
	Wood	3	67	100	100	100
	Vinyl	612	85	93	97	100
	Unknown	5	80	80	100	100

Table 6-8. Continued

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 µg/ft²	75 µg/ft²	100 µg/ft²	Interim Clearance Standard
Window Sill						
Maryland	All	2411	67	75	80	100
	Wood	1651	67	75	80	100
	Vinyl	106	85	91	92	100
	Aluminum	44	73	77	84	100
	Other	18	78	83	83	100
	Unknown	592	61	71	77	100
HUD FHA	All	689	52	63	69	100
	Unknown	689	52	63	69	100
HUD PHA	All	412	68	81	85	100
	Unknown	412	68	81	85	100
HUD Grantee (High)*	All	4906	73	81	85	100
	Wood	587	61	70	78	100
	Vinyl	34	85	88	91	100
	Other	3976	76	83	87	100
	Unknown	309	56	64	71	100
HUD Grantee (Low)**	All	2170	59	71	80	100
	Wood	485	52	64	74	100
	Vinyl	33	76	79	82	100
	Other	1550	61	73	83	100
	Unknown	102	59	66	70	100
Atlantic City	All	46	63	72	83	100
	Unknown	46	63	72	83	100
Cleveland	All	93	62	70	80	100
	Unknown	93	62	70	80	100
Dover	All	11	9	9	9	100
	Wood	4	0	0	0	100
	Vinyl	1	0	0	0	100
	Aluminum	4	25	25	25	100
	Unknown	2	0	0	0	100

Table 6-8. Continued

Data Source	Substrate	Sample Size	Percentage of Samples Below			
			50 $\mu g/ft^2$	75 $\mu g/ft^2$	100 $\mu g/ft^2$	Interim Clearance Standard
Window Trough						
Maryland	All	1827	50	58	64	100
	Wood	373	38	47	52	100
	Vinyl	575	58	65	71	100
	Aluminum	282	55	63	70	100
	Unknown	597	48	56	61	100
HUD FHA	All	423	24	33	37	100
	Unknown	423	24	33	37	100
HUD PHA	All	371	58	77	84	100
	Unknown	371	58	77	84	100
HUD Grantee (High)*	All	3036	64	72	77	100
	Wood	32	50	63	69	100
	Vinyl	1577	71	78	83	100
	Other	1218	56	65	72	100
	Unknown	209	49	61	67	100
HUD Grantee (Low)**	All	1341	40	52	61	100
	Wood	51	41	47	51	100
	Vinyl	224	74	79	83	100
	Other	953	32	46	56	100
	Unknown	113	41	50	56	100
Atlantic City	All	267	76	83	85	100
	Unknown	267	76	83	85	100
Cleveland	All	39	64	67	72	100
	Unknown	39	64	67	72	100
Dover	All	260	79	85	89	100
	Vinyl	180	76	82	87	100
	Aluminum	11	91	91	91	100
	Other	2	50	50	50	100
	Unknown	67	85	94	96	100

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-9a. Percentiles ($\mu g/ft^2$) for Floor Dust-Loading by Data Source and Substrate for the First Site Visit.

Data Source	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Maryland	All	2750	19	85	181	330	1128
	Wood	1082	18	77	159	297	892
	Vinyl	660	21	99	200	360	1399
	Other	19	84	116	725	1110	1110
	Unknown	989	17	82	182	347	2580
HUD FHA	All	967	48	187	418	871	3119
	Unknown	967	48	187	418	871	3119
HUD PHA	All	558	48	111	200	312	600
	Unknown	558	48	111	200	312	600
HUD Grantee (High)*	All	8179	12	47	110	227	1030
	Wood	2027	15	66	163	293	1430
	Vinyl	4067	11	41	87	189	917
	Other	2076	12	47	110	206	754
	Unknown	9	27	41	88	88	88
HUD Grantee (Low)**	All	3642	16	39	76	168	664
	Wood	1774	16	37	62	134	505
	Vinyl	1510	15	35	68	164	569
	Other	358	20	93	189	359	1162
Atlantic City	All	554	10	55	130	230	700
	Unknown	554	10	55	130	230	700
Cleveland	All	158	27	87	190	320	440
	Unknown	158	27	87	190	320	440
Dover	All	633	5	44	68	107	317
	Wood	3	31	61	61	61	61
	Vinyl	625	5	44	68	107	317
	Unknown	5	9	72	96	96	96

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-9b. Percentiles ($\mu g/ft^2$) for Window Sill Dust-Loading by Data Source and Substrate for the First Site Visit.

Data Source	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Maryland	All	2465	28	181	511	1373	5646
	Wood	1687	24	144	376	864	3593
	Vinyl	97	12	47	116	420	6619
	Aluminum	40	10	84	186	280	4078
	Other	18	12	55	327	406	406
	Unknown	623	48	439	1351	2785	9500
HUD FHA	All	668	52	271	714	1678	9054
	Unknown	668	52	271	714	1678	9054
HUD PHA	All	411	28	80	175	281	1175
	Unknown	411	28	80	175	281	1175
HUD Grantee (High)*	All	4798	17	84	202	418	1870
	Wood	636	41	186	390	787	3650
	Vinyl	37	20	58	477	2580	23400
	Other	4120	16	72	169	359	1509
	Unknown	5	29	2066	3901	3901	3901
HUD Grantee (Low)**	All	2147	38	106	171	356	1568
	Wood	507	51	129	215	411	1179
	Vinyl	35	16	110	277	592	5337
	Other	1605	35	100	158	312	1506
Atlantic City	All	51	31	150	380	660	790
	Unknown	51	31	150	380	660	790
Cleveland	All	93	33	125	190	250	1700
	Unknown	93	33	125	190	250	1700
Dover	All	18	443	1263	1624	2276	2276
	Wood	9	718	1263	1624	1624	1624
	Vinyl	1	212	212	212	212	212
	Aluminum	4	443	467	467	467	467
	Unknown	4	993	2276	2276	2276	2276

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-9c. Percentiles ($\mu g/ft^2$) for Window Trough Dust-Loading by Data Source and Substrate for the First Site Visit.

Data Source	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Maryland	All	1985	92	844	3124	9482	49803
	Wood	458	283	2160	7299	16642	59606
	Vinyl	551	43	239	684	1530	10187
	Aluminum	286	51	337	983	2581	38896
	Unknown	690	133	1372	5695	15066	63784
HUD FHA	All	442	375	2569	5810	9150	50534
	Unknown	442	375	2569	5810	9150	50534
HUD PHA	All	371	42	85	167	268	1089
	Unknown	371	42	85	167	268	1089
HUD Grantee (High)*	All	3002	30	150	396	937	7600
	Wood	34	53	189	440	1719	7600
	Vinyl	1626	21	95	227	450	1875
	Other	1341	46	255	722	1833	12452
	Unknown	1	1727	1727	1727	1727	1727
HUD Grantee (Low)**	All	1346	81	285	692	1527	7088
	Wood	65	172	919	1570	1868	17588
	Vinyl	238	17	123	307	1200	5708
	Other	1043	97	312	680	1505	9019
Atlantic City	All	258	10	70	190	450	2130
	Unknown	258	10	70	190	450	2130
Cleveland	All	39	33	170	530	850	2900
	Unknown	39	33	170	530	850	2900
Dover	All	265	7	65	137	202	1829
	Vinyl	185	7	77	152	222	2040
	Aluminum	11	10	16	16	106	106
	Other	2	136	239	239	239	239
	Unknown	67	7	12	68	88	643

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-10a. Percentiles ($\mu g/ft^2$) for Floor Dust-Loading by Data Source and Substrate for the Passed Clearance Site Visit.

Data Source	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Maryland	All	2712	16	60	98	128	181
	Wood	1052	15	58	88	121	180
	Vinyl	651	18	69	106	135	181
	Other	20	67	105	116	118	120
	Unknown	989	15	56	98	134	184
HUD FHA	All	997	40	102	141	165	191
	Unknown	997	40	102	141	165	191
HUD PHA	All	554	43	93	118	148	185
	Unknown	554	43	93	118	148	185
HUD Grantee (High)*	All	8345	12	39	70	108	173
	Wood	1859	13	44	76	120	180
	Vinyl	3875	10	34	57	92	169
	Other	1968	11	35	72	110	170
	Unknown	643	17	60	99	135	179
HUD Grantee (Low)**	All	3749	15	34	57	90	163
	Wood	1716	16	33	52	79	161
	Vinyl	1446	14	31	48	77	151
	Other	324	16	56	104	140	171
	Unknown	263	16	46	79	113	163
Atlantic City	All	545	10	46	80	120	170
	Unknown	545	10	46	80	120	170
Cleveland	All	154	20	54	78	120	177
	Unknown	154	20	54	78	120	177
Dover	All	620	5	43	61	82	145
	Wood	3	31	61	61	61	61
	Vinyl	612	5	43	60	81	145
	Unknown	5	9	72	96	96	96

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-10b. Percentiles ($\mu g/ft^2$) for Window Sill Dust-Loading by Data Source and Substrate for the Passed Clearance Site Visit.

Data Source	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Maryland	All	2411	21	101	201	295	457
	Wood	1651	20	99	193	295	454
	Vinyl	106	12	37	66	167	420
	Aluminum	44	11	83	149	234	325
	Other	18	12	55	327	406	406
	Unknown	592	32	119	238	315	475
HUD FHA	All	689	47	164	263	358	481
	Unknown	689	47	164	263	358	481
HUD PHA	All	412	27	68	150	222	378
	Unknown	412	27	68	150	222	378
HUD Grantee (High)*	All	4906	17	72	141	236	410
	Wood	587	33	116	224	309	472
	Vinyl	34	19	37	77	133	477
	Other	3976	14	60	124	212	406
	Unknown	309	40	128	213	296	381
HUD Grantee (Low)**	All	2170	36	99	145	215	372
	Wood	485	47	114	161	222	393
	Vinyl	33	14	77	127	277	366
	Other	1550	32	92	130	182	368
	Unknown	102	37	190	309	360	426
Atlantic City	All	46	30	90	180	270	380
	Unknown	46	30	90	180	270	380
Cleveland	All	93	33	120	170	230	388
	Unknown	93	33	120	170	230	388
Dover	All	11	361	443	443	467	467
	Wood	4	262	376	376	376	376
	Vinyl	1	212	212	212	212	212
	Aluminum	4	443	467	467	467	467
	Unknown	2	398	434	434	434	434

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-10c. Percentiles ($\mu g/ft^2$) for Window Trough Dust-Loading by Data Source and Substrate for the Passed Clearance Site Visit.

Data Source	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Maryland	All	1827	50	231	400	571	753
	Wood	373	88	338	530	655	747
	Vinyl	575	38	163	308	515	753
	Aluminum	282	38	168	322	456	778
	Unknown	597	53	257	412	604	754
HUD FHA	All	423	169	431	598	678	760
	Unknown	423	169	431	598	678	760
HUD PHA	All	371	41	81	138	213	399
	Unknown	371	41	81	138	213	399
HUD Grantee (High)*	All	3036	27	116	237	389	691
	Wood	32	49	155	210	440	571
	Vinyl	1577	20	82	164	298	585
	Other	1218	37	150	304	464	722
	Unknown	209	50	207	391	560	694
HUD Grantee (Low)**	All	1341	68	198	346	512	725
	Wood	51	77	267	490	646	769
	Vinyl	224	16	78	158	284	619
	Other	953	84	214	352	505	725
	Unknown	113	69	319	516	581	735
Atlantic City	All	267	10	66	170	320	650
	Unknown	267	10	66	170	320	650
Cleveland	All	39	33	170	490	540	648
	Unknown	39	33	170	490	540	648
Dover	All	260	7	59	111	157	404
	Vinyl	180	7	67	140	169	404
	Aluminum	11	10	16	16	106	106
	Other	2	136	239	239	239	239
	Unknown	67	7	12	68	88	643

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

6.3 OBJECTIVE 3: CHARACTERIZATION OF THE CORRELATION BETWEEN COMPONENTS SAMPLED FROM WITHIN THE SAME WORK AREA

The relationships among floor, window sill, and window trough dust-lead wipe samples collected from within the same room are an important aspect of examining a clearance testing program. One method of assessing the relationships is to estimate the linear correlation coefficients. Table 6-11 below displays the Pearson product-moment correlation coefficients and the associated sample sizes for the ln-transformed loading measurements of individual floor, window sill, and window trough samples taken within the same room during a given site visit by data source.

For the first site visit, floor sample results were positively correlated with both window sill and window trough sample results. The correlation between window sills and window troughs was also positive and was generally the strongest of the three correlations from the first site visit. Second site visit correlations follow the same general pattern as those observed during the first site visit, but the linear relationships are not as strong. The correlations from the third site visits are difficult to interpret because of the small number of samples from which they were estimated. No correlations are displayed for the fourth and fifth site visits because very few samples were available.

The conditional probabilities of a sample passing or failing a HUD Interim Guideline clearance standard are given in Tables 6-12a to 6-12d. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second set of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Tables 6-12a to 6-12c, results from contingency table estimates and normal theory estimates are consistent. For both types of estimates and both subsets of data included in the analysis, the probability that one component passes clearance given that another component passes clearance ranged from 60% to 100% between floors and window sills, from 66% to 100% between floors and window troughs, and from 34% to 100% between window sills and troughs.

For both types of estimates and both sets of data included in the analysis, the probability that one component fails clearance testing given that another component in the same room fails clearance testing ranged from 0% to 54% between floors and window sills, from 0% to 59% between floors and window troughs, and from 0% to 79% between window sills and troughs. The probability that a sample collected from a window trough is greater than 800 $\mu g/ft^2$, given

that a sample collected from the window sill is greater than 500 $\mu g/ft^2$, is fairly high for some data sources, ranging from 72% to 79% for Maryland and HUD FHA data.

Another use of the conditional probabilities is to estimate the probability that samples from a given component type will pass clearance, given that samples collected from both of the other two component types in the same room had already passed clearance. For example,

$$\Pr(\text{Troughs} < 800\ \mu g/ft^2 \mid \text{Floors} < 200\ \mu g/ft^2, \text{Sills} < 500\ \mu g/ft^2)$$

is such a conditional probablility.

Table 6-12d shows these types of conditional probabilities. To estimate these conditional probabilities, another set of clearance data was developed, consisting of clearance dust-lead loadings from rooms in which samples from <u>all</u> <u>three</u> component types (floors, sills, and troughs) were collected simultaneously during the first site visit. The conditional probabilities were estimated using two different statistical methods. The first method used the clearance data to derive an empirical estimate of the conditional probabilities (i.e., count the number of rooms in which all three component types passed clearance, and divide by the number of rooms in which floors and sills passed clearance). The second method was to assume that the natural log transformed (ln-transformed) lead loadings from floors, sills, and troughs jointly follow a multivariate normal distribution, and calculate the conditional probabilities. Due to complications associated with computing the tail area probabilities for multivariate normal distributions using triple integrals, the second method conditional probability estimates were calculated via simulation.

When estimating the conditional probabilities using the second method, tests were conducted to determine whether the observed dust-lead loading data from floors, sills, and troughs met the assumption of jointly following a multivariate normal distribution. Due to the fact that there were many observations that were below the detection limit in these data, there were departures from normality in each of the marginal distributions. Thus, the joint data from all three component types fail the assumption of following a multivariate normal distribution. The large proportion of non-detects is likely to bias the second method conditional probability estimates. Therefore, the first method empirical procedures should provide more accurate estimates of these conditional probabilities.

For those clearance dust-lead loadings from rooms in which samples from all three component types were collected simultaneously during the first site visit, when none were greater than or equal to HUD Interim Guideline clearance standards, zero probabilities were shown in the contingency table estimates column in Table 6-12d. However, non-zero probabilities for the normal theory estimates were obtained since they were distributional estimates and were calculated by simulation.

Table 6-11. Observed Within-Room Correlation Coefficients Between Dust-Lead Loading Measurements Collected From Floors, Window Sills, and Window Troughs.

Data Source	Observed Within Room Correlation Coefficients Between					
	Floors and Sills		Floors and Troughs		Sills and Troughs	
	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n	$\rho_{Sills\ Troughs}$	n
First Site Visit						
Maryland	0.534 [a]	1739	0.415 [a]	1340	0.694 [a]	1489
HUD FHA	0.388 [a]	581	0.360 [a]	415	0.651 [a]	375
HUD PHA	0.417 [a]	213	0.352 [a]	192	0.580 [a]	201
HUD Grantee (High)*	0.464 [a]	3021	0.395 [a]	1558	0.394 [a]	324
HUD Grantee (Low)**	0.477 [a]	1687	0.402 [a]	809	0.593 [a]	20
Atlantic City	0.323	26	0.646 [a]	33	.	0
Cleveland	0.142	64	0.297	24	0.467	13
Dover	0.155	13	0.117	184	1.000	2
Second Site Visit						
Maryland	0.313 [a]	86	0.277 [b]	84	0.554 [a]	123
HUD FHA	0.356 [b]	45	0.119	61	0.200	55
HUD PHA	.	1	-0.793	3	.	1
HUD Grantee (High)*	0.297 [a]	101	-0.048	51	0.696 [a]	15
HUD Grantee (Low)**	0.202	21	0.526 [b]	16	-1.000	2
Atlantic City	.	0	0.099	8	.	0
Cleveland	.	0	.	0	.	0
Third Site Visit						
Maryland	0.322	7	-0.343	7	0.412	16
HUD FHA	-0.042	12	-0.308	14	0.586 [b]	17
HUD PHA	.	0	.	0	.	0
HUD Grantee (High)*	0.311	18	-0.087	5	.	0
HUD Grantee (Low)**	1.000	2	.	1	.	0
Atlantic City	.	0	.	0	.	0
Cleveland	.	0	.	0	.	0

[a] Statistically significantly different from zero at the 0.01 level.
[b] Statistically significantly different from zero at the 0.05 level.

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-12a. Conditional Probabilities for Floors and Window Sills Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit Data.

Data Source	Contingency Table Estimates		Normal Theory Estimates		Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
	$P(F<200 \mid S<500)$				$P(F \geq 200 \mid S \geq 500)$			
Maryland	0.927	0.936	0.939	0.942	0.358	0.379	0.323	0.3194
HUD FHA	0.855	0.843	0.850	0.854	0.313	0.300	0.374	0.3873
HUD PHA	0.933	0.935	0.964	0.966	0.000	0	0.277	0.4015
HUD Grantee (High) *	0.961	0.955	0.937	0.935	0.211	0.125	0.275	0.3282
HUD Grantee (Low) * *	0.974	0.900	0.961	0.919	0.132	0.500	0.214	0.2882
Atlantic City	0.956	.	0.998	.	0.000	.	0.009	.
Cleveland	0.921	0.875	0.951	0.930	.	.	0.095	0.2342
Dover	1.000	1.000	0.955	.	0.000	.	0.075	.
	$P(S<500 \mid F<200)$				$P(S \geq 500 \mid F \geq 200)$			
Maryland	0.927	0.930	0.943	0.947	0.358	0.403	0.306	0.3017
HUD FHA	0.882	0.860	0.889	0.875	0.265	0.272	0.297	0.3453
HUD PHA	0.989	0.994	0.998	0.999	0	0.000	0.020	0.0123
HUD Grantee (High) *	0.970	0.965	0.938	0.953	0.169	0.100	0.273	0.2580
HUD Grantee (Low) * *	0.971	0.900	0.935	0.885	0.142	0.5	0.320	0.3746
Atlantic City	0.880	.	0.957	.	0.000	.	0.232	.
Cleveland	1.000	1.000	0.994	0.983	0.000	0.000	0.012	0.0649
Dover	0.692	1.000	0.599	.	.	.	0.535	.

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-12b. Conditional Probabilities for Floors and Window Troughs Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit Data.

Data Source	Contingency Table Estimates		Normal Theory Estimates		Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
	P(F<200|T<800)				P(F ≥200|T ≥800)			
Maryland	0.941	0.942	0.951	0.953	0.224	0.238	0.174	0.1826
HUD FHA	0.858	0.873	0.869	0.878	0.279	0.268	0.299	0.2935
HUD PHA	0.941	0.939	0.968	0.967	0.200	0.200	0.175	0.1903
HUD Grantee (High) *	0.964	0.951	0.936	0.929	0.109	0.000	0.223	0.2524
HUD Grantee (Low) * *	0.960	0.900	0.953	0.939	0.137	0.500	0.173	0.2657
Atlantic City	0.935	.	0.960	.	0.000	.	0.506	.
Cleveland	0.956	0.875	0.964	0.936	0.000	.	0.121	0.2531
Dover	0.983	1.000	0.988	.	0.000	.	0.028	.
	P(T<800|F<200)				P(T ≥800|F ≥200)			
Maryland	0.829	0.823	0.819	0.806	0.487	0.522	0.479	0.5241
HUD FHA	0.668	0.664	0.681	0.676	0.537	0.560	0.572	0.5882
HUD PHA	0.977	0.977	0.992	0.991	0.083	0.083	0.048	0.0560
HUD Grantee (High) *	0.951	0.965	0.930	0.951	0.145	0.000	0.240	0.1835
HUD Grantee (Low) * *	0.918	0.900	0.891	0.799	0.256	0.500	0.343	0.5852
Atlantic City	0.935	.	0.995	.	0.000	.	0.106	.
Cleveland	0.956	1.000	0.967	0.962	0.000	0.000	0.111	0.1628
Dover	0.977	1.000	0.997	.	0.000	.	0.006	.

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-12c. **Conditional Probabilities for Window Sills and Window Troughs Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit Data.**

Data Source	Contingency Table Estimates		Normal Theory Estimates		Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
	P(S<500|T<800)				P(S ≥500|T ≥800)			
Maryland	0.972	0.969	0.978	0.978	0.353	0.372	0.251	0.2518
HUD FHA	0.928	0.930	0.945	0.943	0.318	0.318	0.349	0.3501
HUD PHA	0.994	0.994	0.999	0.999	0.000	0.000	0.043	0.0350
HUD Grantee (High) *	0.971	0.965	0.949	0.945	0.100	0.142	0.202	0.2072
HUD Grantee (Low) * *	0.941	0.900	0.926	0.922	0.666	0.500	0.366	0.3496
Atlantic City	.	.	.	.	.	.	.	.
Cleveland	1.000	1.000	0.986	0.990	.	.	0.108	0.2292
Dover	0.500	1.000	0.339	.	.	.	1.000	.
	P(T<800|S<500)				P(T ≥800|S ≥500)			
Maryland	0.843	0.853	0.820	0.823	0.782	0.767	0.765	0.7651
HUD FHA	0.700	0.693	0.712	0.709	0.721	0.733	0.789	0.7869
HUD PHA	0.975	0.973	0.991	0.990	0.000	0.000	0.283	0.3359
HUD Grantee (High) *	0.971	0.970	0.949	0.949	0.100	0.125	0.201	0.1916
HUD Grantee (Low) * *	0.941	0.900	0.852	0.815	0.666	0.500	0.556	0.5923
Atlantic City	.	.	.	.	.	.	.	.
Cleveland	1.000	1.000	0.963	0.963	.	.	0.253	0.5316
Dover	1.000	1.000	1.000	.	0.000	.	0.297	.

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-12d. Conditional Probabilities for Floors, Window Sills, and Window Troughs Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit Data.

Data Source	Contingency Table Estimates		Normal Theory Estimates		Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
	P(F<200|S<500,T<800)				P(F ≥200|S ≥500,T ≥800)			
Maryland	.	0.947	.	0.957	.	0.427	.	0.3457
HUD FHA	.	0.877	.	0.887	.	0.340	.	0.4146
HUD PHA	.	0.939	.	0.968	.	.	.	0.5287
HUD Grantee (High) *	.	0.954	.	0.942	.	0.000	.	0.4816
HUD Grantee (Low) * *	.	1.000	.	0.948	.	0.000	.	0.3724
Atlantic City	.	.	.	.	.	.	.	.
Cleveland	.	0.875	.	0.937	.	.	.	0.2974
Dover	.	1.000	.	.	.	.	.	.
	P(S<500|F<200,T<800)				P(S ≥500|F ≥200,T ≥800)			
Maryland	.	0.975	.	0.982	.	0.666	.	0.4767
HUD FHA	.	0.935	.	0.954	.	0.405	.	0.4946
HUD PHA	.	0.994	.	0.999	.	0.000	.	0.0973
HUD Grantee (High) *	.	0.969	.	0.958	.	.	.	0.3953
HUD Grantee (Low) * *	.	1.000	.	0.931	.	0.000	.	0.4900
Atlantic City	.	.	.	.	.	.	.	.
Cleveland	.	1.000	.	0.991	.	.	.	0.2693
Dover	.	1.000	.	.	.	.	.	.
	P(T<800|F<200,S<500)				P(T ≥800|F ≥200,S ≥500)			
Maryland	.	0.863	.	0.837	.	0.863	.	0.8281
HUD FHA	.	0.722	.	0.737	.	0.833	.	0.8425
HUD PHA	.	0.977	.	0.991	.	.	.	0.4423
HUD Grantee (High) *	.	0.969	.	0.956	.	0.000	.	0.2811
HUD Grantee (Low) * *	.	1.000	.	0.840	.	0.000	.	0.7655
Atlantic City	.	.	.	.	.	.	.	.
Cleveland	.	1.000	.	0.969	.	.	.	0.6751
Dover	.	1.000	.	.	.	.	.	.

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

6.4 OBJECTIVE 4: DEMONSTRATION OF THE IMPACT OF COMPOSITE SAMPLING ON PASS/FAIL RATES OF HOMES

Table 6-13 lists the number of housing units investigated by component type and the number of individual samples collected within a housing unit. For example, Table 6-13 shows, for the Maryland data, that there were five floor dust-wipe, window sill dust-wipe, and window trough dust-wipe samples taken during the first site visit for 88, 77, and 67 housing units, respectively. As explained in Section 5.4, within a component type, multiple simulated composite samples were created for housing units containing more than four samples. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples. As can be calculated in Table 6-13, for the HUD Grantee High group data, five or more floor dust samples were collected from 766 of 2,092 homes (or 37% of the homes). Similarly, five or more samples were collected from window sills and window troughs, of 3% (66/2,031) and 1% (22/1,697) of the homes, respectively.

For each combination of component type and composite clearance criterion (Standard Rule, Standard/n Rule, and 2×Standard/n Rule), each housing unit either passed clearance, failed clearance, or yielded inconclusive results. The numbers of housing units in these categories are presented in Table 6-14. Inconclusive results were only possible for those housing units which contained more than four individual samples; the many possible ways of combining five or more individual sample lead-loadings into multiple simulated composite samples had the potential of resulting in a variety of different outcomes under each of the three composite clearance criteria. However, Table 6-14 shows that the percentage of housing units with greater than four individual clearance samples of a given component type that resulted in inconclusive results was low, ranging from 1.5% (4/263, HUD Grantee Low data, 2xStandard/n Rule) to 19.2% (24/125, HUD FHA data, Standard/n Rule) for the evaluation of floor samples. (The HUD Grantee Low data group had 263 housing units and the HUD FHA data had 125 housing units which contained more than four individual floor samples; these were shown in Tables D2-5 and B-5, respectively.) A more detailed description of the methods used to categorize a simulated composite result as pass, fail, or inconclusive is provided in Section 5.4.

Table 6-15 presents the performance characteristics used to evaluate the composite clearance criteria for each component type in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The calculation of the performance statistics is discussed in Section 5.4. These performance characteristics are sensitivity, specificity,

positive predictive value (PPV), and negative predictive value (NPV), which are defined as follows:

Sensitivity = Pr(Fail Composite Sample Clearance | Fail Individual Sample Clearance)

Specificity = Pr(Pass Composite Sample Clearance | Pass Individual Sample Clearance)

PPV = Pr(Fail Individual Sample Clearance | Fail Composite Sample Clearance)

NPV = Pr(Pass Individual Sample Clearance | Pass Composite Sample Clearance)

If the primary purpose of conducting clearance testing is to prevent potential lead exposure for residents, then one might choose a composite sample clearance criterion with high sensitivity at the expense of high specificity. By design, the Standard/n Rule always sacrifices specificity for sensitivity; the sensitivity for the Standard/n Rule is always 1.000 while the specificity for this rule is estimated at 0.487 to 0.944 for floors, 0.875 to 1.000 for window sills, and 0.723 to 1.000 for window troughs.

On the other hand, the Standard Rule always sacrifices sensitivity for specificity. The specificity for the Standard Rule is always 1.000 while the sensitivity for this rule is estimated at 0.182 to 0.627 for floors, 0.250 to 1.000 for window sills, and 0.200 to 1.000 for window troughs. The 2×Standard/n Rule attempts to maximize both sensitivity and specificity simultaneously. For the 2×Standard/n Rule, the values of sensitivity are higher than those calculated for the Standard Rule, while the values of specificity are higher than those calculated for the Standard/n Rule. (There are only a few cases of equality for the smaller data sets.) Estimates of sensitivity and specificity in these examples are always conservative, because inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

It is evident that all three composite clearance testing criteria have different specificity and sensitivity error rates as estimated empirically. The error rates correspond to the consistency between clearance decisions and the true lead levels present in the various locations sampled (assuming the individual sample lead-loading results are representative of these lead hazards). To further characterize the performance of each criterion, the logistic regression model described

in Section 5.4 was fitted for each combination of component type and composite clearance criteria to describe the relationship between the probability of passing clearance and the maximum lead-loading present in all of the sampling locations tested in a housing unit.

Tables 6-16a to 6-16c list, for floor, window sill, and window trough dust-lead loadings, and for different composite clearance criteria, the parameter estimates and associated standard errors for the logistic regression model. In addition, the estimated probability of clearance for a component when the maximum individual sample lead loading is greater than or equal to 1/2, 1, 2, and 4 times the associated HUD Interim Guidelines Clearance Standard [2] is presented. Figures which illustrate the predicted relationships for each component and each composite clearance criterion are presented in appendices for each individual data source. Tables 6-16a to 6-16b show that, for most of the data sources, under the Standard Rule for composite sampling, there is at least a 50% chance that a housing unit will pass clearance testing for floor and window sill samples even when a lead loading from an individual sample location is twice the HUD Interim Guidelines Clearance Standard. Only two data sources, Maryland and HUD PHA, show this phenomenon for the window trough samples. For the conservative Standard/n Rule the probability of passing clearance is low when the maximum individual sample lead loading is greater than or equal to the HUD Interim Guidelines Clearance Standard, but the probability of passing clearance when the maximum individual sample lead loading is equal to ½ the HUD Interim Guidelines Clearance Standard is between 0.56 and 0.89 for the floor samples, for example. The 2×Standard/n Rule is shown to be a compromise between the Standard and Standard/n Rules. At ½ the HUD Interim Guidelines Clearance Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is nearly one (1.00). At twice the HUD Interim Guidelines Clearance Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is nearly zero in most cases.

Table 6-13. Number of Housing Units for Each Data Source that Contained (N) Individual Clearance Samples of Each Component Type Based on the First Site Visit.

Data Source	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
Floor										
Maryland	65	127	101	108	88	54	54	39	25	661
HUD FHA	2	7	3	8	36	17	17	23	32	145
HUD PHA	6	12	32	16	7	8	25	8	5	119
HUD Grantee (High)*	236	413	334	343	258	288	142	36	42	2092
HUD Grantee (Low)**	129	124	159	346	201	50	7	2	3	1021
Atlantic City	3	57	33	26	23	10	2	2	3	159
Cleveland	0	1	13	10	10	3	0	0	1	38
Dover	3	2	6	111	17	8	1	3	0	151
Window Sill										
Maryland	61	75	121	151	77	46	45	23	13	612
HUD FHA	8	5	21	8	23	23	22	9	7	126
HUD PHA	3	30	23	23	7	24	0	1	0	111
HUD Grantee (High)*	263	1068	501	133	41	20	2	2	1	2031
HUD Grantee (Low)**	120	587	214	40	4	2	0	0	1	968
Atlantic City	3	9	3	4	1	0	0	0	0	20
Cleveland	7	4	13	6	3	0	0	0	0	33
Dover	9	1	1	1	0	0	0	0	0	12
Window Trough										
Maryland	79	99	106	101	67	28	28	13	15	536
HUD FHA	13	8	19	21	24	14	6	2	1	108
HUD PHA	17	15	26	18	32	1	0	1	0	110
HUD Grantee (High)*	732	727	170	46	13	7	1	1	0	1697
HUD Grantee (Low)**	495	302	60	13	3	0	0	0	0	873
Atlantic City	14	79	19	6	1	0	0	0	0	119
Cleveland	14	6	3	1	0	0	0	0	0	24
Dover	32	110	3	1	0	0	0	0	0	146

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-14. Number of Housing Units that Passed or Failed Clearance on the First Site Visit, Based on Individual Sample Clearance Results versus Simulated Composite Clearance Results.

Data Source	Individual Sample Clearance Results	Composite Sample Clearance Results								
		Standard			Standard/n			2xStandard/n		
		Pass	Inconclusive	Fail	Pass	Inconclusive	Fail	Pass	Inconclusive	Fail
Floor										
Maryland	Pass	521	0	0	434	32	55	494	14	13
	Fail	42	36	62	0	0	140	5	28	107
HUD FHA	Pass	78	0	0	38	24	16	68	9	1
	Fail	7	18	42	0	0	67	0	10	57
HUD PHA	Pass	88	0	0	52	9	27	75	8	5
	Fail	20	5	6	0	0	31	2	7	22
HUD Grantee (High)*	Pass	1775	0	0	1622	78	75	1730	28	17
	Fail	97	63	157	0	0	317	8	62	247
HUD Grantee (Low)**	Pass	909	0	0	858	14	37	896	4	9
	Fail	39	18	55	0	0	112	7	13	92
Atlantic City	Pass	127	0	0	119	3	5	126	1	0
	Fail	16	6	10	0	0	32	4	6	22
Cleveland	Pass	27	0	0	20	2	5	26	1	0
	Fail	7	2	2	0	0	11	3	0	8
Dover	Pass	140	0	0	124	2	14	138	0	2
	Fail	5	3	3	0	0	11	1	1	9
Window Sill										
Maryland	Pass	470	0	0	430	18	22	467	2	1
	Fail	35	14	93	0	0	142	8	9	125
HUD FHA	Pass	80	0	0	70	5	5	78	2	0
	Fail	6	13	27	0	0	46	0	7	39
HUD PHA	Pass	103	0	0	97	2	4	100	2	1
	Fail	2	1	5	0	0	8	0	1	7
HUD Grantee (High)*	Pass	1854	0	0	1797	2	55	1829	0	25
	Fail	72	7	98	0	0	177	8	2	167
HUD Grantee (Low)**	Pass	897	0	0	883	0	14	892	0	5

Table 6-14. Continued

Data Source	Individual Sample Clearance Results	Composite Sample Clearance Results								
		Standard			Standard/n			2xStandard/n		
		Pass	Inconclusive	Fail	Pass	Inconclusive	Fail	Pass	Inconclusive	Fail
Atlantic City	Pass	16	0	0	15	0	1	15	0	1
	Fail	3	0	1	0	0	4	2	0	2
Cleveland	Pass	32	0	0	30	1	1	32	0	0
	Fail	0	0	1	0	0	1	0	0	1
Dover	Pass	7	0	0	7	0	0	7	0	0
	Fail	0	0	5	0	0	5	0	0	5
Window Trough										
Maryland	Pass	337	0	0	300	10	27	324	5	8
	Fail	39	16	144	0	0	199	6	15	178
HUD FHA	Pass	47	0	0	34	4	9	45	1	1
	Fail	6	7	48	0	0	61	2	5	54
HUD PHA	Pass	105	0	0	104	1	0	105	0	0
	Fail	2	2	1	0	0	5	0	1	4
HUD Grantee (High)*	Pass	1546	0	0	1527	1	18	1533	0	13
	Fail	33	1	117	0	0	151	2	1	148
HUD Grantee (Low)**	Pass	772	0	0	757	1	14	762	0	10
	Fail	20	0	81	0	0	101	0	0	101
Atlantic City	Pass	114	0	0	109	0	5	111	0	3
	Fail	1	0	4	0	0	5	0	0	5
Cleveland	Pass	22	0	0	22	0	0	22	0	0
	Fail	0	0	2	0	0	2	0	0	2
Dover	Pass	141	0	0	141	0	0	141	0	0
	Fail	2	0	3	0	0	5	0	0	5

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-15. Performance Characteristics of Composite Clearance Criteria for Each Data Source

Data Source	Standard				Standard/n				2xStandard/n			
	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV
Floor												
Maryland	0.443	1.000	1.000	0.925	1.000	0.833	0.718	1.000	0.764	0.948	0.892	0.990
HUD FHA	0.627	1.000	1.000	0.918	1.000	0.487	0.807	1.000	0.851	0.872	0.983	1.000
HUD PHA	0.194	1.000	1.000	0.815	1.000	0.591	0.534	1.000	0.710	0.852	0.815	0.974
HUD Grantee (High)*	0.495	1.000	1.000	0.948	1.000	0.914	0.809	1.000	0.779	0.975	0.936	0.995
HUD Grantee (Low)**	0.491	1.000	1.000	0.959	1.000	0.944	0.752	1.000	0.821	0.986	0.911	0.992
Atlantic City	0.313	1.000	1.000	0.888	1.000	0.937	0.865	1.000	0.688	0.992	1.000	0.969
Cleveland	0.182	1.000	1.000	0.794	1.000	0.741	0.688	1.000	0.727	0.963	1.000	0.897
Dover	0.273	1.000	1.000	0.966	1.000	0.886	0.440	1.000	0.818	0.986	0.818	0.993
Window Sill												
Maryland	0.655	1.000	1.000	0.931	1.000	0.915	0.866	1.000	0.880	0.994	0.992	0.983
HUD FHA	0.587	1.000	1.000	0.930	1.000	0.875	0.902	1.000	0.848	0.975	1.000	1.000
HUD PHA	0.625	1.000	1.000	0.981	1.000	0.942	0.667	1.000	0.875	0.971	0.875	1.000
HUD Grantee (High)*	0.554	1.000	1.000	0.963	1.000	0.969	0.763	1.000	0.944	0.987	0.870	0.996
HUD Grantee (Low)**	0.486	1.000	1.000	0.963	1.000	0.984	0.833	1.000	0.929	0.994	0.929	0.996
Atlantic City	0.250	1.000	1.000	0.842	1.000	0.938	0.800	1.000	0.500	0.938	0.667	0.882
Cleveland	1.000	1.000	1.000	1.000	1.000	0.938	0.500	1.000	1.000	1.000	1.000	1.000
Dover	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 6-15. Continued

Data Source	Standard				Standard/n				2xStandard/n			
	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV
Window Trough												
Maryland	0.724	1.000	1.000	0.896	1.000	0.890	0.881	1.000	0.894	0.961	0.957	0.982
HUD FHA	0.787	1.000	1.000	0.887	1.000	0.723	0.871	1.000	0.885	0.957	0.982	0.957
HUD PHA	0.200	1.000	1.000	0.981	1.000	0.990	1.000	1.000	0.800	1.000	1.000	1.000
HUD Grantee (High)*	0.775	1.000	1.000	0.979	1.000	0.988	0.893	1.000	0.980	0.992	0.919	0.999
HUD Grantee (Low)**	0.802	1.000	1.000	0.975	1.000	0.981	0.878	1.000	1.000	0.987	0.910	1.000
Atlantic City	0.800	1.000	1.000	0.991	1.000	0.956	0.500	1.000	1.000	0.974	0.625	1.000
Cleveland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Dover	0.600	1.000	1.000	0.986	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-16a. Results from Fitting a Logistic Regression Model Which Investigates the Relationship Between the Probability of Clearance and the Maximum Individual Floor Sample Lead Loading, Under Three Different Composite Sampling Decision Rules.

Data Source	Decision Rule	Number of Houses with Simulated Composite Clearance Status of		Estimated Intercept		Estimated Slope		Probability of Clearance when the Maximum Individual Sample Result Within a House is Equal to			
		Pass	Fail	β_0	s.e. (β_0)	β_1	s.e. (β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Maryland	Standard	563	62	6.729	0.728	-0.016	0.002	0.99	0.97	0.55	0.00
	2xStandard/n	499	120	5.784	0.517	-0.026	0.003	0.96	0.66	0.01	0.00
	Standard/n	434	195	6.392	0.606	-0.053	0.005	0.75	0.02	0.00	0.00
HUD FHA	Standard	85	42	5.982	1.170	-0.013	0.003	0.99	0.97	0.71	0.01
	2xStandard/n	68	58	6.907	1.416	-0.025	0.005	0.99	0.86	0.04	0.00
	Standard/n	38	83	6.275	1.435	-0.056	0.012	0.67	0.01	0.00	0.00
HUD PHA	Standard	108	6	7.163	1.804	-0.016	0.005	1.00	0.98	0.69	0.00
	2xStandard/n	77	27	4.499	0.723	-0.020	0.004	0.93	0.64	0.04	0.00
	Standard/n	52	58	6.338	1.307	-0.061	0.013	0.56	0.00	0.00	0.00
HUD Grantee (High)*	Standard	1872	157	6.290	0.384	-0.015	0.001	0.99	0.96	0.57	0.00
	2xStandard/n	1738	264	6.251	0.349	-0.026	0.002	0.97	0.75	0.02	0.00
	Standard/n	1622	392	6.840	0.404	-0.048	0.003	0.89	0.06	0.00	0.00
HUD Grantee (Low)**	Standard	948	55	6.793	0.688	-0.016	0.002	0.99	0.97	0.56	0.00
	2xStandard/n	903	101	6.988	0.669	-0.031	0.003	0.98	0.68	0.00	0.00
	Standard/n	858	149	6.924	0.600	-0.052	0.005	0.85	0.03	0.00	0.00
Atlantic City	Standard	143	10	6.654	1.512	-0.014	0.004	0.99	0.98	0.73	0.01
	2xStandard/n	130	22	6.749	1.480	-0.027	0.006	0.98	0.78	0.01	0.00
	Standard/n	119	37	7.018	1.477	-0.050	0.012	0.89	0.05	0.00	0.00
Cleveland	Standard	34	2	15.387	11.072	-0.041	0.032	1.00	1.00	0.28	0.00
	2xStandard/n	29	8	89.903	81.060	-0.288	0.259	1.00	1.00	0.00	0.00
	Standard/n	20	16	7.685	3.452	-0.072	0.036	0.61	0.00	0.00	0.00
Dover	Standard	145	3	7.874	2.605	-0.016	0.006	1.00	0.99	0.83	0.01
	2xStandard/n	139	11	7.995	2.075	-0.035	0.011	0.99	0.71	0.00	0.00
	Standard/n	124	25	6.084	1.070	-0.051	0.011	0.73	0.02	0.00	0.00

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor. ** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-16b. Results from Fitting a Logistic Regression Model Which Investigates the Relationship Between the Probability of Clearance and the Maximum Individual Window Sill Sample Lead Loading, Under Three Different Composite Sampling Decision Rules.

Data Source	Decision Rule	Number of Houses with Simulated Composite Clearance Status of		Estimated Intercept		Estimated Slope		Probability of Clearance when the Maximum Individual Sample Result Within a House is Equal to			
		Pass	Fail	β_0	s.e. (β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Maryland	Standard	505	93	6.270	0.691	-0.006	0.001	0.99	0.96	0.57	0.00
	2xStandard/n	475	126	7.180	0.871	-0.012	0.002	0.99	0.80	0.01	0.00
	Standard/n	430	164	7.535	0.914	-0.021	0.003	0.90	0.04	0.00	0.00
HUD FHA	Standard	86	27	5.268	1.057	-0.004	0.001	0.98	0.96	0.70	0.03
	2xStandard/n	78	39	5.452	1.149	-0.009	0.002	0.96	0.74	0.03	0.00
	Standard/n	70	51	8.565	2.770	-0.026	0.009	0.90	0.01	0.00	0.00
HUD PHA	Standard	105	5	7.516	2.613	-0.007	0.002	1.00	0.98	0.66	0.00
	2xStandard/n	100	8	6.773	1.804	-0.011	0.004	0.98	0.75	0.01	0.00
	Standard/n	97	12	7.144	1.908	-0.019	0.006	0.91	0.08	0.00	0.00
HUD Grantee (High)*	Standard	1926	98	6.693	0.484	-0.007	0.001	0.99	0.97	0.50	0.00
	2xStandard/n	1837	192	8.134	0.696	-0.017	0.002	0.98	0.41	0.00	0.00
	Standard/n	1797	232	8.146	0.667	-0.021	0.002	0.94	0.07	0.00	0.00
HUD Grantee (Low)**	Standard	931	34	7.354	0.917	-0.007	0.001	1.00	0.98	0.55	0.00
	2xStandard/n	896	70	9.111	1.316	-0.018	0.003	0.99	0.53	0.00	0.00
	Standard/n	883	84	7.754	0.844	-0.018	0.002	0.96	0.19	0.00	0.00
Atlantic City	Standard	19	1	7.509	6.052	-0.009	0.009	0.99	0.95	0.16	0.00
	2xStandard/n	17	3	3.613	1.454	-0.006	0.003	0.90	0.70	0.13	0.00
	Standard/n	15	5	5.362	2.566	-0.014	0.007	0.86	0.15	0.00	0.00
Cleveland	Standard	32	1	58.607	1.23E8	-0.057	158636	1.00	1.00	0.85	0.00
	2xStandard/n	32	1	58.607	1.23E8	-0.057	158636	1.00	1.00	0.85	0.00
	Standard/n	30	2	5.772	2.525	-0.015	0.009	0.89	0.18	0.00	0.00
Dover	Standard	7	5	179.30	6.26E8	-0.303	1.05E6	1.00	1.00	0.00	0.00
	2xStandard/n	7	5	179.30	6.26E8	-0.303	1.05E6	1.00	1.00	0.00	0.00
	Standard/n	7	5	179.30	6.26E8	-0.303	1.05E6	1.00	1.00	0.00	0.00

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor. ** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table 6-16c. **Results from Fitting a Logistic Regression Model Which Investigates the Relationship Between the Probability of Clearance and the Maximum Individual Window Trough Sample Lead Loading, Under Three Different Composite Sampling Decision Rules.**

Data Source	Decision Rule	Number of Houses with Simulated Composite Clearance Status of		Estimated Intercept		Estimated Slope		Probability of Clearance when the Maximum Individual Sample Result Within a House Is Equal to			
		Pass	Fail	β_0	s.e. (β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Maryland	Standard	376	144	6.581	0.804	-0.004	0.001	0.99	0.97	0.52	0.00
	2xStandard/n	330	186	5.887	0.657	-0.006	0.001	0.97	0.70	0.01	0.00
	Standard/n	300	226	6.432	0.769	-0.011	0.001	0.88	0.08	0.00	0.00
HUD FHA	Standard	53	48	6.713	1.883	-0.004	0.001	0.99	0.96	0.46	0.00
	2xStandard/n	47	55	6.127	1.638	-0.006	0.002	0.98	0.81	0.04	0.00
	Standard/n	34	70	5.229	1.379	-0.011	0.003	0.73	0.04	0.00	0.00
HUD PHA	Standard	107	1	7.662	3.513	-0.004	0.002	1.00	0.99	0.88	0.02
	2xStandard/n	105	4	7.503	2.675	-0.009	0.003	0.98	0.64	0.00	0.00
	Standard/n	104	5	110.05	2.500	-0.213	0.000	1.00	0.00	0.00	0.00
HUD Grantee (High)*	Standard	1579	117	8.320	0.882	-0.007	0.001	1.00	0.92	0.03	0.00
	2xStandard/n	1535	161	12.192	1.897	-0.016	0.003	1.00	0.33	0.00	0.00
	Standard/n	1527	169	13.313	2.180	-0.019	0.003	1.00	0.17	0.00	0.00
HUD Grantee (Low)**	Standard	792	81	8.537	1.187	-0.008	0.001	1.00	0.92	0.02	0.00
	2xStandard/n	762	111	12.559	2.302	-0.017	0.003	1.00	0.20	0.00	0.00
	Standard/n	757	115	11.400	1.918	-0.017	0.003	0.99	0.14	0.00	0.00
Atlantic City	Standard	115	4	123.19	3.59E8	-0.086	255018	1.00	1.00	0.00	0.00
	2xStandard/n	111	8	7.623	2.670	-0.012	0.004	0.95	0.17	0.00	0.00
	Standard/n	109	10	8.752	3.520	-0.017	0.007	0.89	0.01	0.00	0.00
Cleveland	Standard	22	2	280.94	8.89E8	-0.375	1.21E6	1.00	0.00	0.00	0.00
	2xStandard/n	22	2	280.94	8.89E8	-0.375	1.21E6	1.00	0.00	0.00	0.00
	Standard/n	22	2	280.94	8.89E8	-0.375	1.21E6	1.00	0.00	0.00	0.00
Dover	Standard	143	3	153.40	9.38E8	-0.105	601328	1.00	1.00	0.00	0.00
	2xStandard/n	141	5	166.03	4.73E8	-0.200	567941	1.00	1.00	0.00	0.00
	Standard/n	141	5	166.03	4.7e+08	-0.2	567941	1.00	1.00	0.00	0.00

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor. ** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

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APPENDIX A

Maryland Department of the Environment

APPENDIX A

MARYLAND DEPARTMENT OF THE ENVIRONMENT

The Lead Enforcement Group within the Maryland Department of the Environment (MDE) has been actively conducting post abatement clearance testing since 1988. When the Lead Enforcement Group first started its clearance testing program, there were no protocols for sampling or standards developed for the purpose of clearance testing. Based on scientific evidence, this program developed protocols for the collection of dust wipe samples from floors, window sills, and window troughs in rooms that had received abatement. The clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs also originated from within the MDE Lead Programs [16]. These standards were based on pilot data, and were designed so that a work area would pass clearance through reasonable cleaning efforts on the part of the lead contractor. These clearance standards also represented levels of post abatement lead on floors, sills and troughs that were far below the levels of lead that would typically be observed on these components prior to abatement. As a result of adopting these standards, Maryland had fewer cases of re-poisoning following abatement.

The Lead Enforcement Group has archived data on dust-lead loading results since they started conducting clearance sampling in 1988. These data existed only in hard copy form, and were made available to EPA for the purposes of this project. All clearance testing sample results collected between January 1, 1991 and January 30, 1995 were entered into an electronic database for the purposes of this investigation. Thus, the statistical analysis of data from MDE represents these four years of clearance testing results throughout the state of Maryland.

If the results from a dust-lead loading sample exceeded the clearance standards, the area had to be recleaned and retested until acceptable results were obtained for each unit. There are no records of additional testing for approximately 23% of the units which failed clearance. These losses to follow-up may be attributed to families moving, litigation, poor record keeping, or on-going clearance testing. Since the Lead Enforcement Group within MDE is a state regulatory program, and not a research program, this loss to follow up within the dataset could not be avoided.

Statistical results presented in the main body of this report summarize the four years of clearance testing as a single unit. Descriptive modelling of each calendar year separately is presented in Section A-2.

A-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

As part of the State of Maryland clearance testing program, 7967 individual dust wipe samples were collected from floors, window sills and window troughs within 3502 rooms in 706 residential units during the four years from January 1991 through January 1995. Table A-1 presents the number of individual samples, work areas and residential units that passed or failed clearance testing within each combination of component type and site visit. Approximately 90% (7200/7967) of the dust samples were collected during the first site visit to a residential unit. Although 87% (6289/7200) of the dust samples fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs, only 80% (2762/3450) of the rooms and 57% (402/706) of the residential units passed clearance on the first site visit. This increase in the failure rate from individual samples to rooms and residential units is attributable to the fact that if any individual sample exceeds the standard and fails clearance, then both the room and residential unit also fail clearance. Of the 304 residential units that failed clearance on the first site visit, 168 (55%) of these residential units were revisited for a second clearance testing. Eventually, 543 of the 706 residential units (77%) are known to have passed clearance testing.

The failure rate for individual samples during the first site visit was highest for window trough samples at 21% (408/1,985), followed by window sills at 10% (254/2,465) and floors at 9% (249/2,750). This pattern is reflected in the failure rates for residential units based on results from individual components: 37% (199/536) of the residential units would have failed based on the results of window trough samples, 23% (142/612) of the residential units would have failed based on the results of window sill samples, and 21% (140/661) of the residential units would have failed based on the results of floor samples.

Table A-1. Clearance Testing Results by Individual Sample, Room, and Dwelling Unit for the State of Maryland Regulatory Program (January 1991 - January 1995)

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	2501	249	2750	2413	243	2656	521	140	661
	Sill	2211	254	2465	2121	250	2371	470	142	612
	Trough	1577	408	1985	1455	399	1854	337	199	536
	All	6289	911	7200	2762	688	3450	402	304	706
Second	Floor	185	22	207	178	22	200	82	15	97
	Sill	169	25	194	164	23	187	67	11	78
	Trough	227	48	275	213	47	260	91	24	115
	All	581	95	676	347	75	422	132	36	168
Third	Floor	23	0	23	23	0	23	10	0	10
	Sill	28	2	30	20	2	22	3	2	5
	Trough	19	8	27	19	7	26	7	5	12
	All	70	10	80	39	9	48	14	5	19
Fourth	Floor	3	0	3	3	0	3	1	0	1
	Sill	3	0	3	3	0	3	1	0	1
	Trough	4	1	5	4	1	5	2	1	3
	All	10	1	11	6	1	7	2	1	3
Total	Floor	2712	271	2983	2558	131	2689	592	70	662
	Sill	2411	281	2692	2243	166	2409	525	89	614
	Trough	1827	465	2292	1649	256	1905	434	107	541
	All	6950	1017	7967	3077	425	3502	543	163	706

A-2. Objective 2: Characterization of the Distribution of the Dust-lead Loadings, Geometric Mean Dust-lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

Preliminary assessment of the data indicated that the distribution of dust-lead loading clearance sample results was highly skewed. A natural logarithm transformation was applied to the data.

Table A-2 gives the geometric means for each component type by site visit for data collected in Maryland between January 1991 and January 1995. A 95% confidence interval for the geometric mean dust-lead loading for each combination of site visit and component type is also provided. In general, the within-house (or room-to-room) variability is smaller than the between-house variability; however, all of the variance components are within a single order of magnitude. The length of the confidence intervals for any given component type increases successively from the first site visit to the third. This increase in length is due primarily to the decrease by orders of magnitude in the sample size used to estimate the variance components between site visits.

The geometric means and their 95% confidence intervals are used to compare trends between site visits for a given component tested, and to compare average results between component types within a site visit. If the 95% confidence intervals on two geometric means do not overlap then these two geometric means are statistically significantly different at a level less than 0.05. For the Maryland data, the floor dust-lead loading clearance geometric means are less than the window sills, which are in turn less than the window troughs within a site visit. However, the geometric means for a given component are not significantly different across the three site visits based on comparing the 95% confidence intervals. These results also generally hold across individual years, as seen in Tables A-2.1 through A-2.5.

Figures A-1 and A-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures A-3 to A-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures A-6 to A-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

Table A-2. Clearance Testing Geometric Mean and Variance Component Estimates By Site Visit and Component Type for Maryland by Site Visit and Component Type.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ($\mu g/ft^2$)	σ_{Within} ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	2750	2656	661	22	1.18	0.95	20	25
	Sill	2465	2371	612	42	1.50	1.14	37	48
	Trough	1985	1854	536	144	1.84	1.37	122	171
Second	Floor	207	200	97	29	1.03	1.07	22	38
	Sill	194	187	78	56	1.65	0.92	37	83
	Trough	275	260	115	114	1.47	1.15	83	156
Third	Floor	23	23	10	31	0.86	0.66	15	62
	Sill	30	22	5	45	1.64	0.85	6	366
	Trough	27	26	12	193	1.32	1.28	67	554

Table A-2.1. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for Maryland Properties First Abated in 1991.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	628	593	133	28	1.21	0.92	22	34
	Sill	621	581	125	45	1.43	1.11	34	59
	Trough	411	384	93	195	2.04	1.16	125	302
Second	Floor	59	54	27	40	0.84	1.35	24	67
	Sill	57	51	22	111	2.04	1.13	42	296
	Trough	81	73	27	174	1.71	1.31	80	377
Third	Floor	6	6	3	13	0.78	0.65	1	133
	Sill	18	10	2	60	2.64	0.53	0	1.28E12
	Trough	8	7	3	132	2.13	1.07	0	40300

Table A-2.2. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for Maryland Properties First Abated in 1992.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$) Lower Bound	Upper Bound
First	Floor	798	776	156	19	1.00	0.98	16	23
	Sill	723	700	158	30	1.44	1.03	23	38
	Trough	534	516	126	107	1.72	1.17	77	148
Second	Floor	42	42	22	24	1.05	0.84	14	41
	Sill	44	44	16	49	1.72	0.74	19	127
	Trough	67	66	31	103	1.19	1.11	60	176
Third	Floor	1	1	1	1	0.00	0.00	.	.
	Trough	3	3	2	422	1.02	1.65	0	1.98E9
Fourth	Trough	1	1	1	1	0.00	0.00	.	.

Table A-2.3. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for Maryland Properties First Abated in 1993.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean (µg/ft²)	$\sigma_{Between}$ ln (µg/ft²)	σ_{Within} ln (µg/ft²)	95% Confidence Interval on Geometric Mean (µg/ft²)	
								Lower Bound	Upper Bound
First	Floor	603	589	177	22	1.19	0.92	18	27
	Sill	584	567	170	38	1.34	1.21	30	47
	Trough	464	450	150	150	1.70	1.35	110	204
Second	Floor	55	54	29	23	1.33	0.80	13	40
	Sill	49	49	25	49	1.41	1.01	25	97
	Trough	67	67	34	147	1.51	0.99	81	266
Third	Floor	13	13	4	34	0.80	0.70	8	143
	Sill	12	12	3	37	1.25	1.23	1	1203
	Trough	14	14	5	210	1.19	1.34	33	1350
Fourth	Floor	3	3	1	45	0.00	1.14	0	0
	Sill	3	3	1	112	0.00	1.25	0	0
	Trough	4	4	2	314	0.58	0.51	1	17600

Table A-2.4. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for Maryland Properties First Abated in 1994.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	704	681	188	22	1.28	0.95	18	27
	Sill	521	508	153	64	1.66	1.24	48	86
	Trough	564	493	162	147	1.86	1.70	106	206
Second	Floor	51	50	19	32	0.88	1.06	19	55
	Sill	44	43	15	29	0.87	0.71	17	50
	Trough	60	54	23	54	1.26	1.06	29	103
Third	Floor	3	3	2	75	1.01	0.19	0	712000
	Trough	2	2	2	69	1.97	0.91	0	1.97E10

Table A-2.5. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for Maryland Properties First Abated in 1995.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	17	17	7	24	1.17	1.12	7	86
	Sill	16	15	6	22	0.90	1.11	7	74
	Trough	12	11	5	140	1.22	0.64	28	710

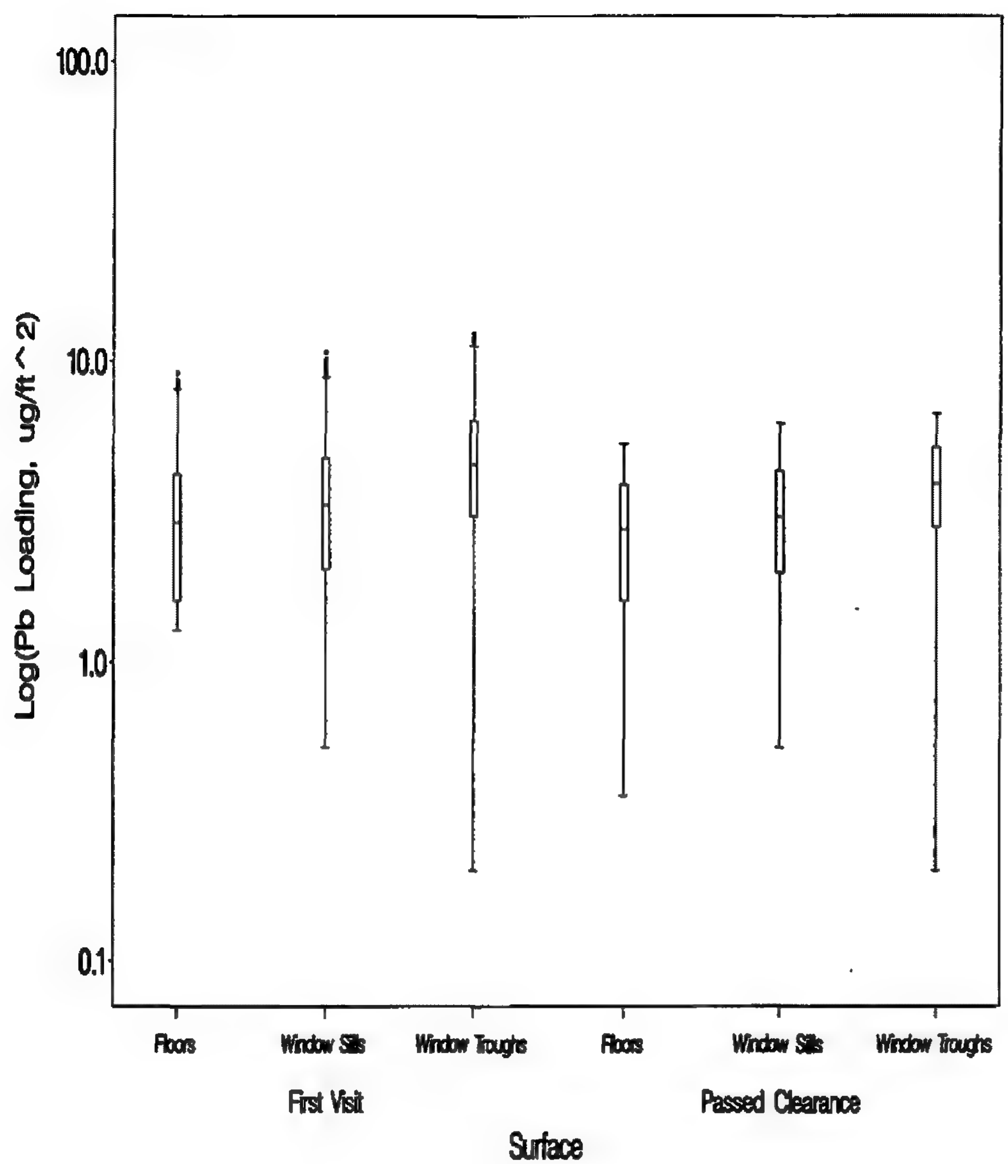

Figure A-1. Comparison of ln-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.

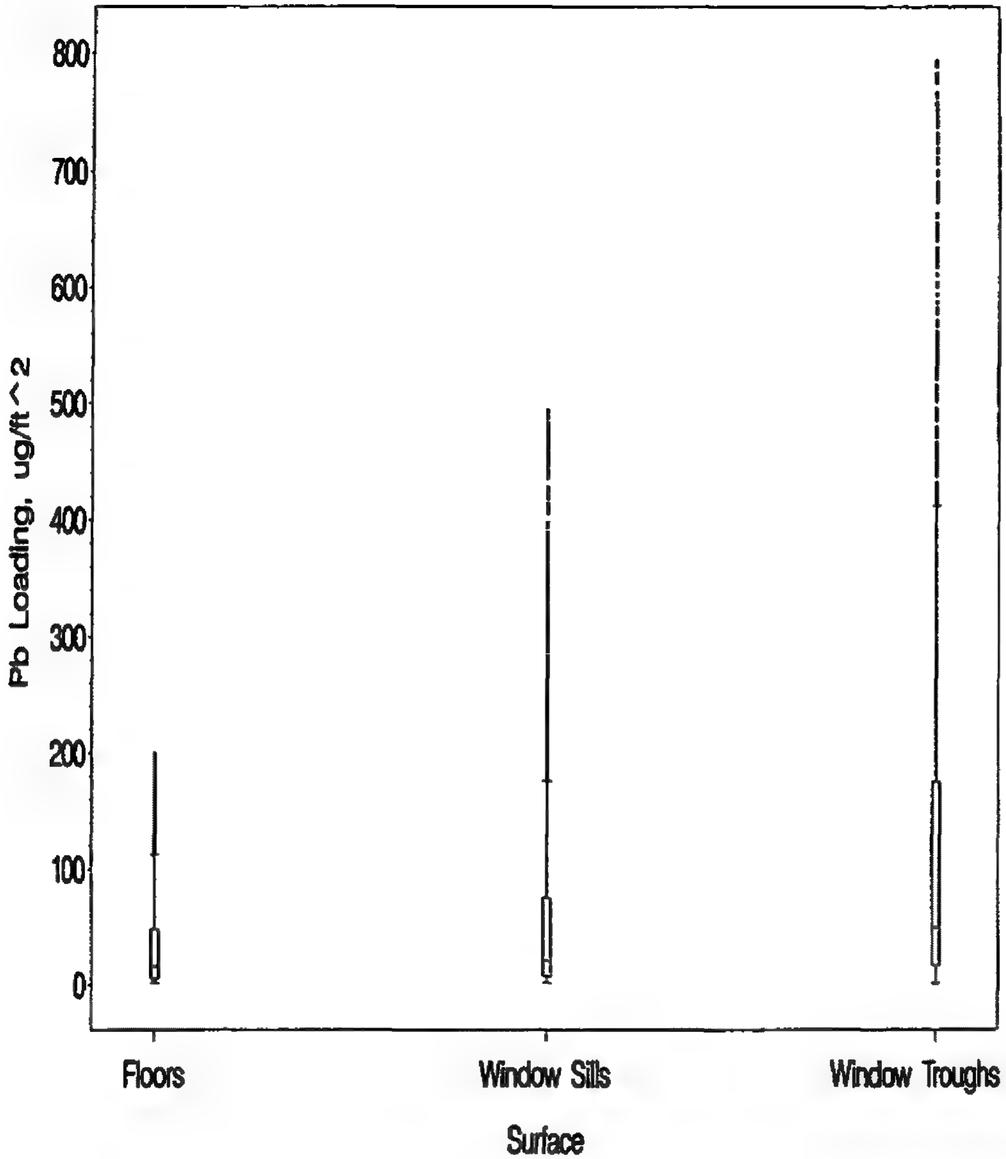

Figure A-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

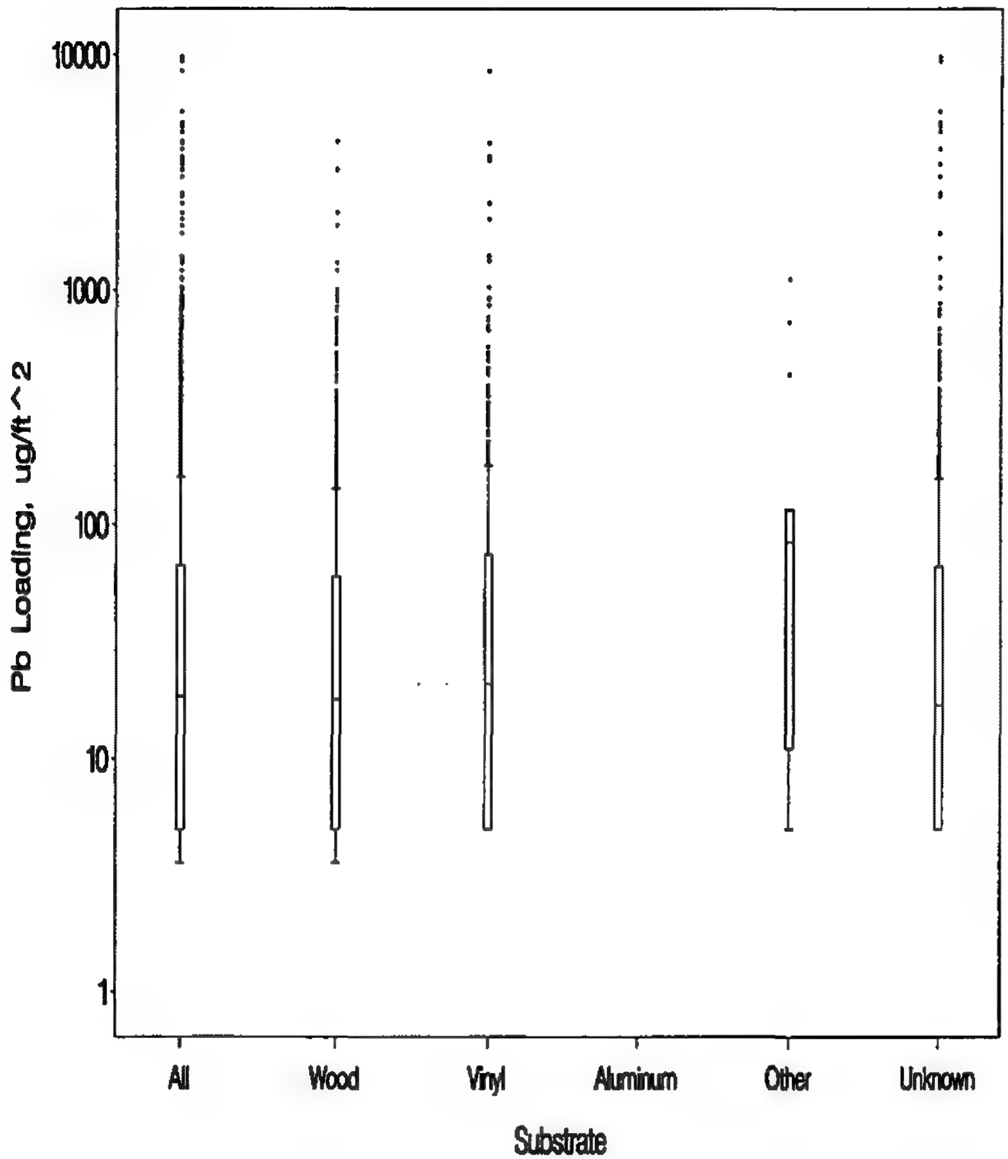

Figure A-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

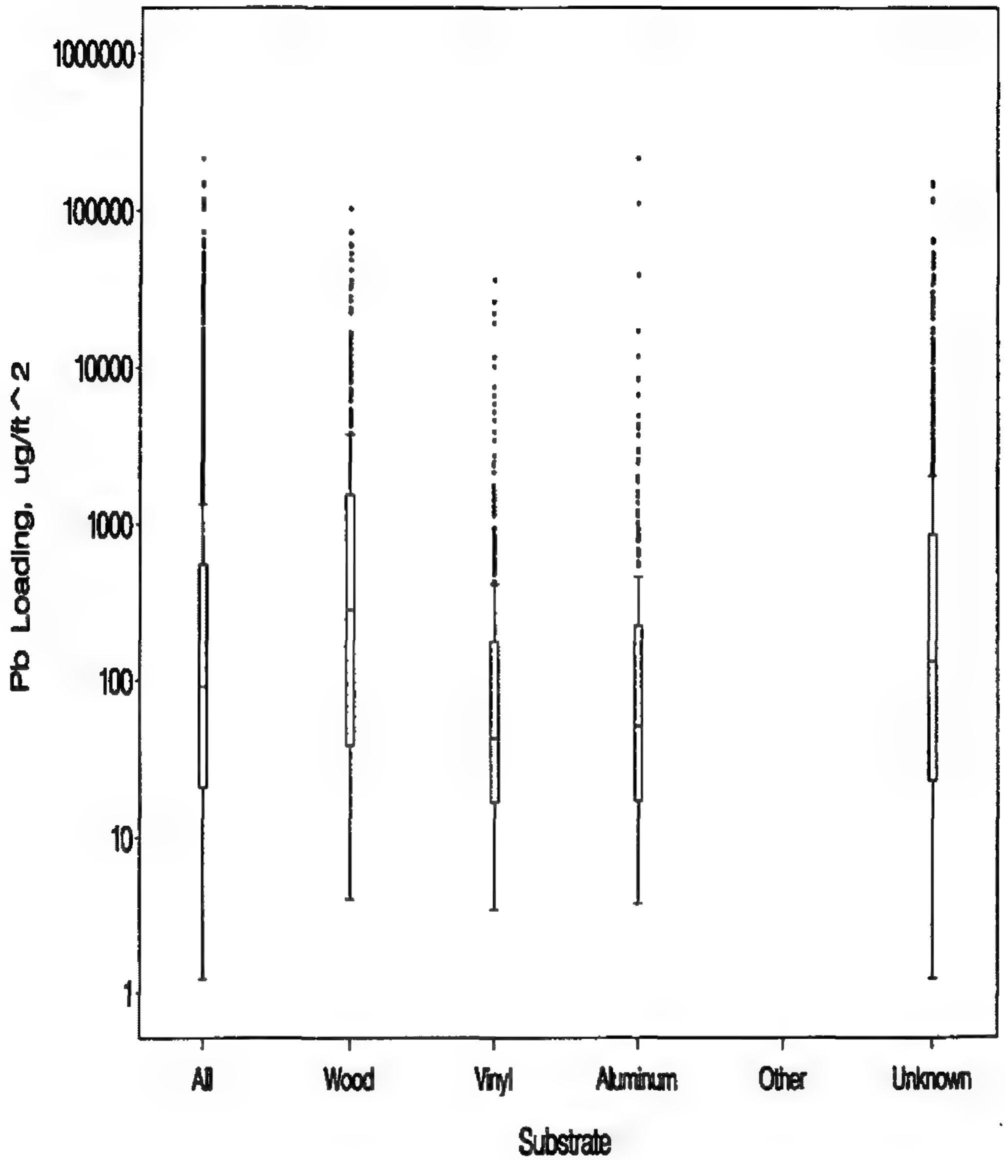

Figure A-4. **Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.**

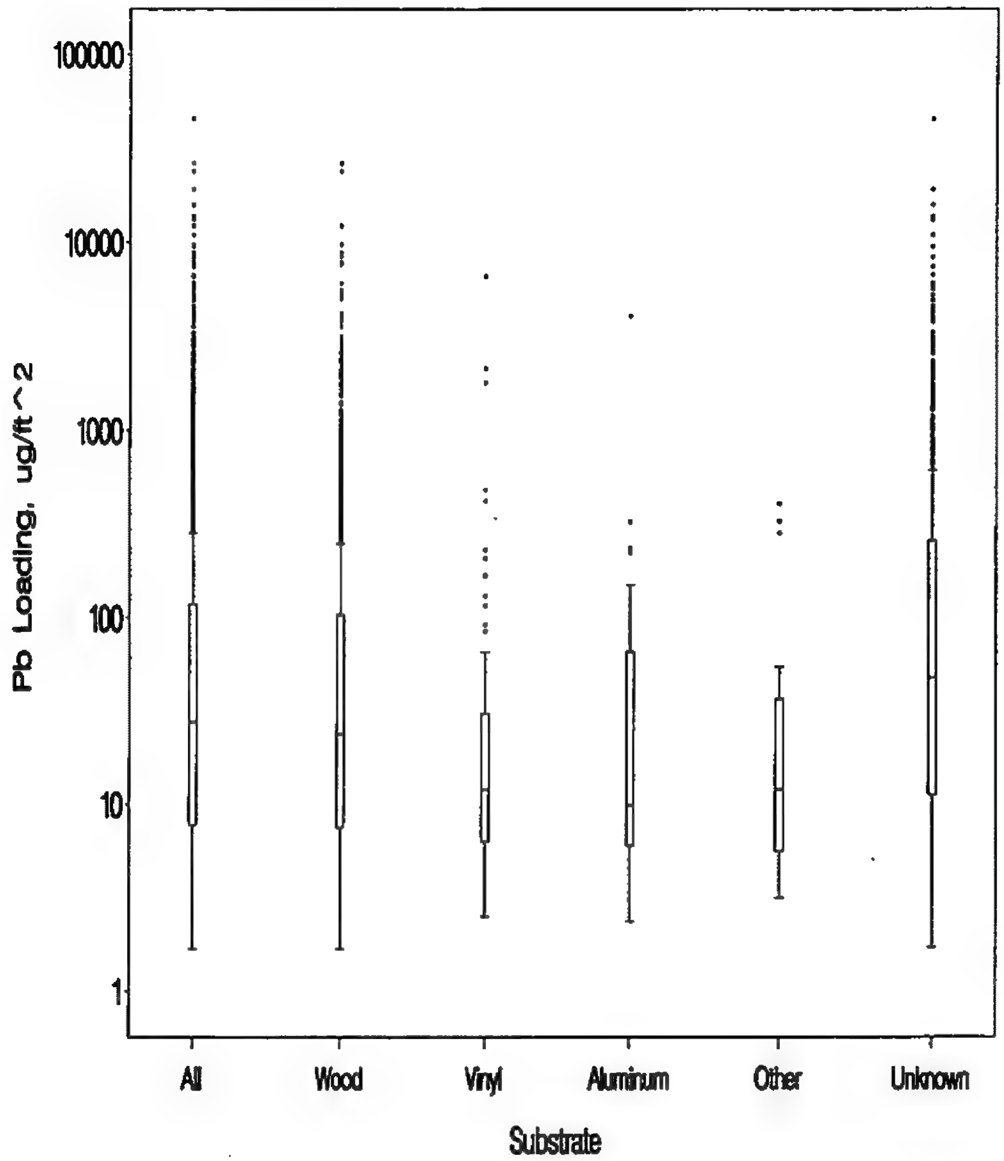

Figure A-5. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.

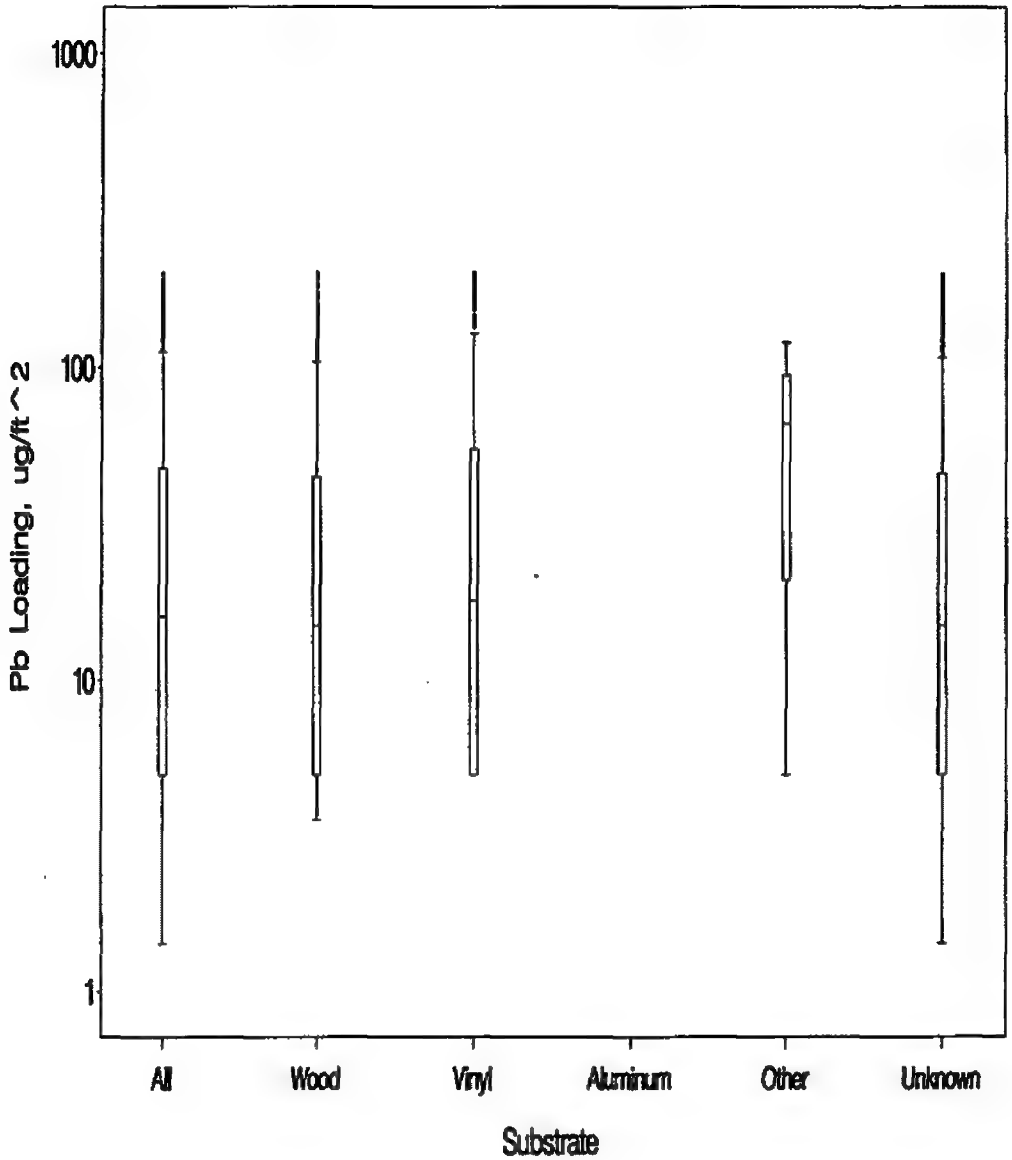

Figure A-6. **Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.**

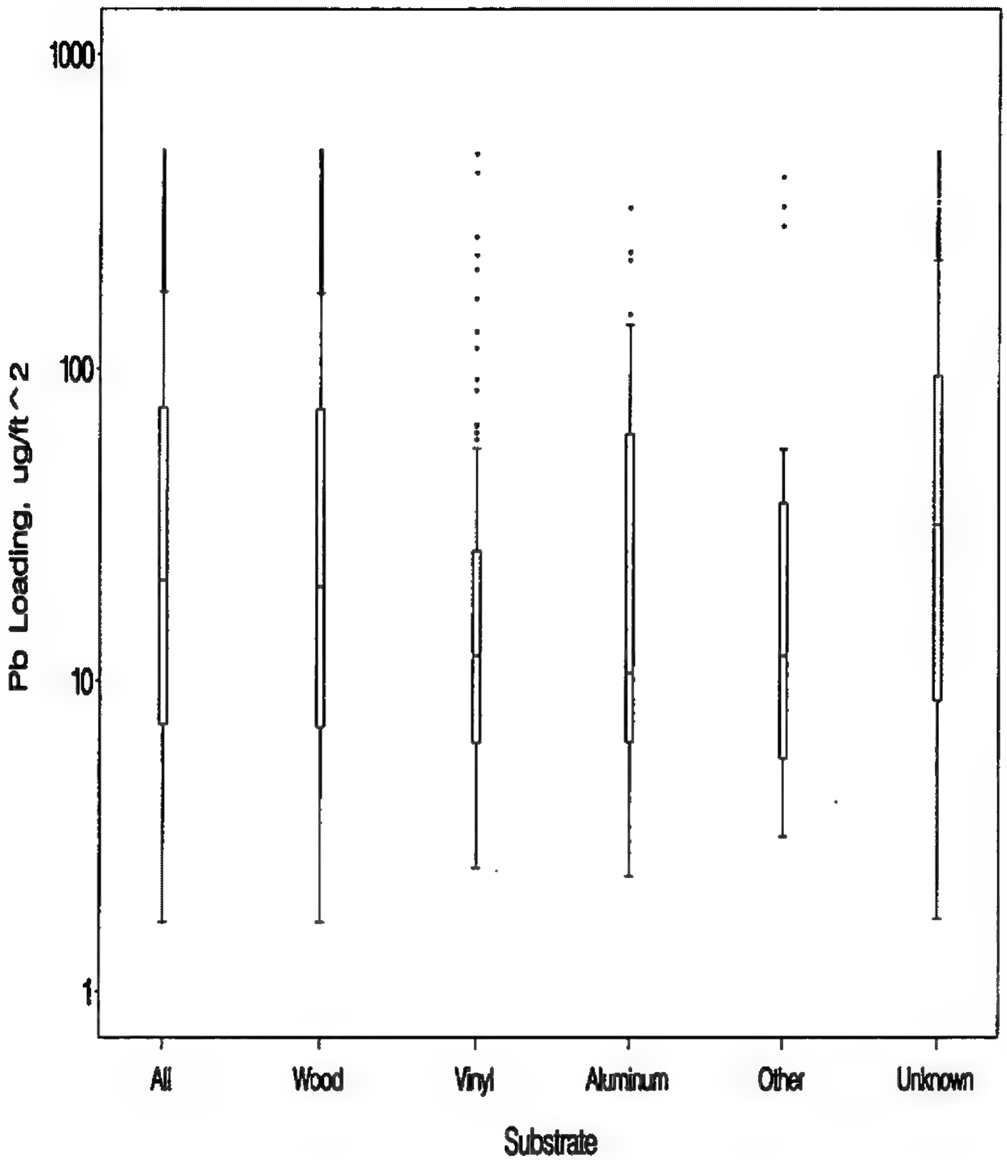

Figure A-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

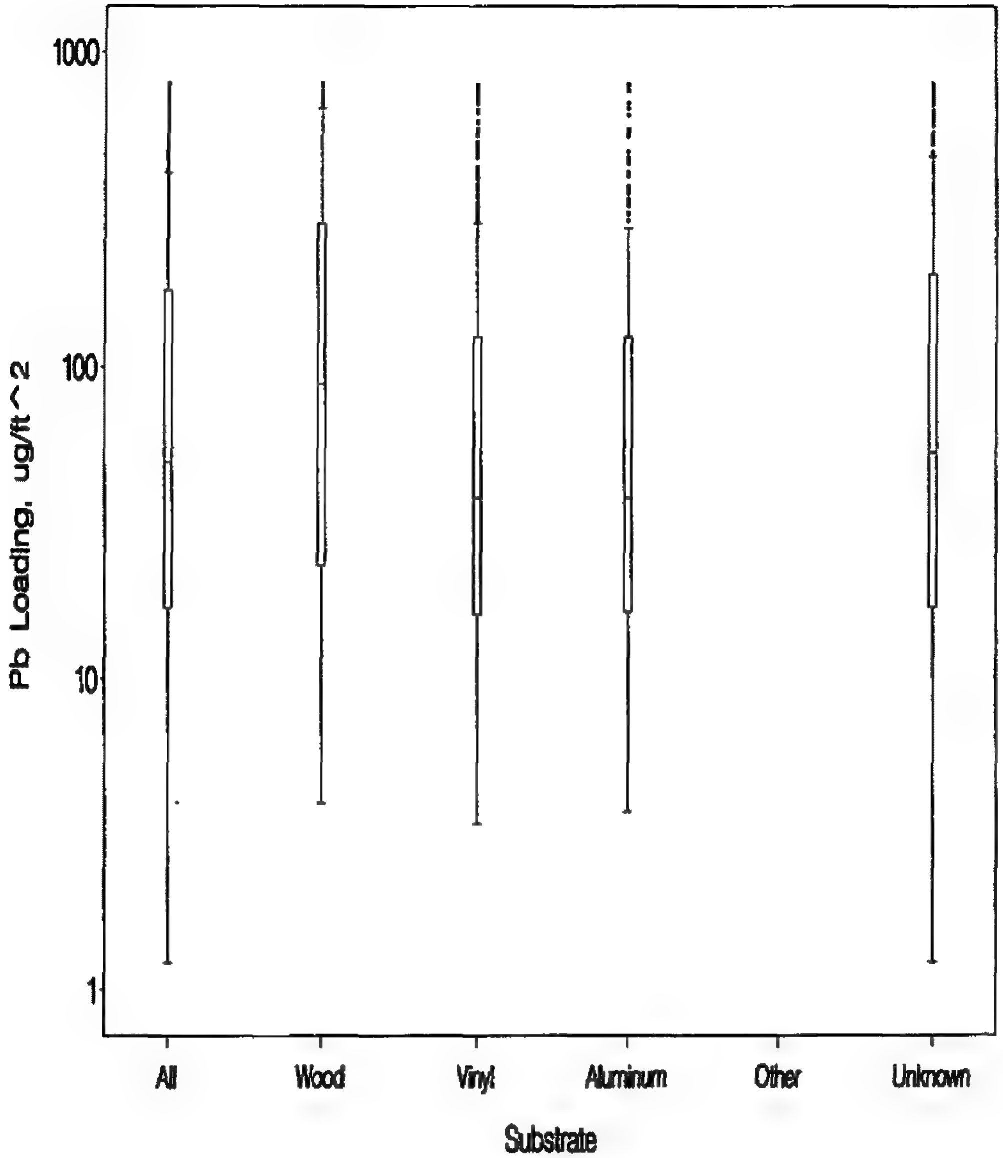

Figure A-8. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

A-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships among floor, window sill, and window trough wipe samples are another important aspect of examining a clearance testing program. One method of assessing the relationship between individual floor, window sill, and window trough wipe samples collected from the same room is to estimate linear correlation coefficients. Table A-3 displays the Pearson product-moment correlation coefficients and the associated sample size for the log lead loading measurements of individual floor, window sill, and window trough samples taken within the same room. Results from the first site visit show that floor samples are positively correlated with both window sill and window trough samples. The correlation between window sills and window troughs is also positive and is the highest of any observed correlation from the first site visit. All observed correlations from the first site visit are significant at the 0.01 level. The correlations from the second site visit follow the same general pattern as those observed during the first site visit, but are not as strong. These correlations observed at the second site visit are all significant at either the 0.05 or 0.01 level. The correlations from the third site visit are difficult to interpret because of the small number of samples from which they were estimated.

The conditional probabilities of a sample passing or failing a standard are given in Table A-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Table A-4, results from contingency table estimates and normal theory estimates are consistent. For both types of estimates and both data sets included in the analysis, the probability that one component passes clearance given that another component passes clearance ranges from 81% to 98%. The probability that a window sill sample is less than 500 $\mu g/ft^2$, given that the samples from the window troughs are less than 800 $\mu g/ft^2$, is among the highest values at 97 to 98%.

For both types of estimates and both data sets included in the analysis, the probability that one component fails clearance testing given that another component in the same room fails clearance testing ranged from 17% to 78%. The probability that a sample collected from a

window trough is greater than or equal to 800 $\mu g/ft^2$, given that a sample collected from the window sill is greater than or equal to 500 $\mu g/ft^2$, is fairly high (greater than 76%).

Table A-3. Observed Within-Room Correlation Coefficients Between Dust-Lead Loading Measurements Collected From Floors, Window Sills and Window Troughs For the Maryland Data.

Site Visit	Observed Within Room Correlation Coefficients Between					
	Floors and Sills		Floors and Troughs		Sills and Troughs	
	$\rho_{Floors, Sills}$	n	$\rho_{Floors, Troughs}$	n	$\rho_{Sills, Troughs}$	n
First	0.53[a]	1739	0.42[a]	1340	0.69[a]	1489
Second	0.31[a]	86	0.28[b]	84	0.55[a]	123
Third	0.32	7	-0.34	7	0.41	16

[a] Statistically significantly different from zero at the 0.01 level.
[b] Statistically significantly different from zero at the 0.05 level.

A-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

First site visit data from the Maryland Department of the Environment included 7,200 individual sample lead loading clearance sample results collected from floors, window sills, and troughs in 3,450 rooms within 706 dwelling units. Individual sample lead loading results from each component type within a residential unit were combined to construct simulated composite sample results.

Table A-5 provides, for each component type, the number of residential units that were investigated by the number of individual samples that were collected. For example, there were 88 residential units which included five floor dust-wipe samples on the first site visit. Residential units containing more than four samples from a component type resulted in the estimation of multiple simulated composite sample results in this analysis. Therefore, summing all the units that had five or more individual samples, approximately 40% (260/661), 33% (204/612), and 28% (151/536) of the residential units resulted in the estimation of multiple simulated composite samples from floors, window sills, and window troughs, respectively.

When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples.

Table A-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
P(F<200|S<500)	0.927	0.936	0.939	0.942	P(F≥200|S≥500)	0.358	0.379	0.323	0.319
P(S<500|F<200)	0.927	0.930	0.943	0.947	P(S≥500|F≥200)	0.358	0.403	0.306	0.302
P(F<200|T<800)	0.941	0.942	0.951	0.953	P(F≥200|T≥800)	0.224	0.238	0.174	0.183
P(T<800|F<200)	0.829	0.823	0.819	0.806	P(T≥800|F≥200)	0.487	0.522	0.479	0.524
P(S<500|T<800)	0.972	0.969	0.978	0.978	P(S≥500|T≥800)	0.353	0.372	0.251	0.252
P(T<800|S<500)	0.843	0.853	0.820	0.823	P(T≥800|S≥500)	0.782	0.767	0.765	0.765
P(F<200|S<500,T<800)	.	0.947	.	0.957	P(F≥200|S≥500,T≥800)	.	0.427	.	0.346
P(S<500|F<200,T<800)	.	0.975	.	0.982	P(S≥500|F≥200,T≥800)	.	0.666	.	0.477
P(T<800|F<200,S<500)	.	0.863	.	0.837	P(T≥800|F≥200,S≥500)	.	0.863	.	0.828

For each component type within a residential unit, the set of individual clearance sample lead loading results was used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria (Standard, Standard/n, and 2×Standard/n). Table A-6 shows, for each combination of component type and composite clearance criterion, the number of residential units that passed clearance, failed clearance, or yielded inconclusive results. Inconclusive results were only possible for those residential units which contained more than four individual samples; the many possible ways of combining five or more individual sample lead-loadings into multiple simulated composite samples had the potential of resulting in a variety of different outcomes under each of the three composite clearance criteria. However, the percentage of residential units with greater than four individual clearance samples of a given component type that resulted in inconclusive results was low, ranging from 5.4% (11/204) for the evaluation of window sill samples under the 2×Standard/n Rule to 16.2% (42/260) for the evaluation of floor samples under the 2×Standard/n Rule.

Table A-5. Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data from the Maryland Department Data.

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	65	61	79
2	127	75	99
3	101	121	106
4	108	151	101
5	88	77	67
6	54	46	28
7	54	45	28
8	39	23	13
9+	25	13	15
Total	661	612	536
Total with N≥5	260	204	151

Table A-6. Individual Sample Clearance Results versus Simulated Composite Clearance Data from the Maryland Data.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	521	42	470	35	337	39
	Inconclusive	0	36	0	14	0	16
	Fail	0	62	0	93	0	144
Standard/n	Pass	434	0	430	0	300	0
	Inconclusive	32	0	18	0	10	0
	Fail	55	140	22	142	27	199
2 x Standard/n	Pass	494	5	467	8	324	6
	Inconclusive	14	28	2	9	5	15
	Fail	13	107	1	125	8	178

The performance characteristics of each combination of component type and composite clearance criteria are presented in Table A-7 in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). These performance statistics are based on empirical estimates of the following conditional probabilities:

Sensitivity = Pr(Fail Composite Sample Clearance | Fail Individual Sample Clearance)
Specificity = Pr(Pass Composite Sample Clearance | Pass Individual Sample Clearance)
PPV = Pr(Fail Individual Sample Clearance | Fail Composite Sample Clearance)
NPV = Pr(Pass Individual Sample Clearance | Pass Composite Sample Clearance)

If the primary purpose of conducting clearance testing is to prevent potential lead exposure for residents, then one might choose a composite sample clearance criteria with high sensitivity at the expense of high specificity. By design, the Standard/n Rule always sacrifices specificity for sensitivity; the sensitivity for the Standard/n Rule is always 1.00 while the specificity for this rule is estimated at 0.83 for floors, 0.92 for window sills, and 0.89 for window troughs. On the other hand, the Standard Rule always sacrifices sensitivity for specificity. The specificity for the Standard Rule is always 1.00 while the sensitivity for this rule is estimated at

Table A-7. Performance Characteristics of Composite Clearance Criteria Based on the Maryland Data.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2×Standard/n
Floors	Sensitivity	0.44	1.00	0.76
	Specificity	1.00	0.83	0.95
	PPV	1.00	0.72	0.89
	NPV	0.93	1.00	0.99
Window Sills	Sensitivity	0.66	1.00	0.88
	Specificity	1.00	0.92	0.99
	PPV	1.00	0.87	0.99
	NPV	0.93	1.00	0.98
Window Troughs	Sensitivity	0.72	1.00	0.89
	Specificity	1.00	0.89	0.96
	PPV	1.00	0.88	0.96
	NPV	0.90	1.00	0.98

0.44 for floors, 0.66 for window sills, and 0.72 for window troughs. The 2×Standard/n Rule attempts to maximize both sensitivity and specificity. For the 2×Standard/n Rule, the values of sensitivity are higher than those calculated for the Standard Rule, while the values of specificity are higher than those calculated for the Standard/n Rule. Estimates of sensitivity and specificity in these examples are always conservative, because inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

It is evident that all three composite clearance testing criteria have different specificity and sensitivity rates as estimated empirically using the clearance data from the Maryland Department of the Environment. These rates correspond to the consistency between clearance decisions and the true lead hazards present in the various locations sampled (assuming the individual sample lead loading results are representative of these lead hazards). To further characterize the performance of each of the three composite clearance criterion, the following logistic regression model was fitted for each combination of component type and composite clearance criteria to describe the relationship between the probability of passing clearance and the maximum lead-loading present in all of the sampling locations tested in a residential unit:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

For each component type, the estimated relationship between the probability of passing clearance and the maximum lead-loading is presented graphically in Figure A-9. In this figure, the solid, long dashed, and finely dashed lines represent the estimated relationship for the Standard, Standard/n, and 2×Standard/n Rules respectively.

Table A-8 provides parameter estimates and associated standard errors from the logistic regression models, as well as estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2 and 4 times the associated HUD standard for individual samples. Results from fitting these logistic regression models to clearance data from the Maryland Department of the Environment show that under the Standard Rule for composite sampling, there is a better than 50% chance that a residential unit will pass clearance testing when there is an individual sample location which has a lead-loading level that is equal to twice the HUD recommended clearance standard. The estimated relationship for the Standard/n Rule demonstrates this rule's high sensitivity (probability of passing is low when the maximum individual sample lead loading is greater than or equal to the HUD Standard) along with the loss in specificity for this rule (probability of passing is between 0.75 and 0.90 when the maximum individual sample lead loading is equal to ½ HUD Standard). Once again, the 2×Standard/n Rule is shown to be a compromise between the Standard and Standard/n Rules. At ½ HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is nearly one, and at 2×HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is nearly zero.

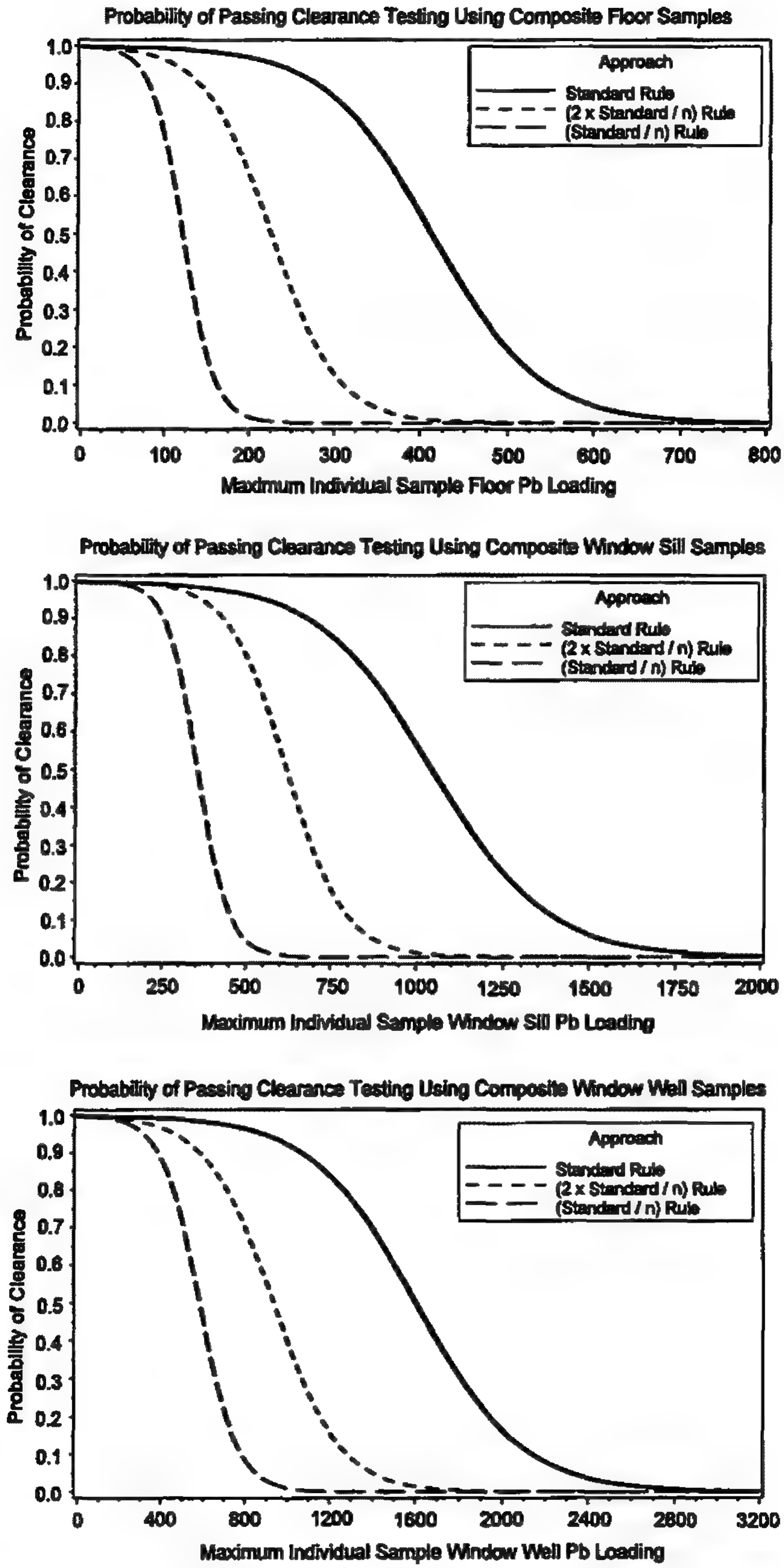

Figure A-9. **Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Result by Component Type Based on Simulated Composite Samples from the Maryland Department of the Environment.**

Table A-8. Results from a Logistic Regression Model Which Investigates the Relationship Between the Probability of Clearance and the Maximum Individual Sample Lead Loading, Under Three Different Composite Sampling Decision Rules, Using the Maryland Data.

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of:			Estimated Intercept		Estimated Slope		Probability of Clearance when the maximum individual sample result within a house is equal to:			
		Pass	Inconclusive	Fail	β_0	s.e.(β_0)	β_1	s.e.(β_1)	½*HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Floors	Standard	563	36	62	6.729	0.728	-0.016	0.002	0.99	0.97	0.55	0.00
	2 × Standard/n	499	42	120	5.784	0.517	-0.026	0.003	0.96	0.66	0.01	0.00
	Standard/n	434	32	195	6.392	0.606	-0.053	0.005	0.75	0.02	0.00	0.00
Window Sills	Standard	505	14	93	6.270	0.691	-0.006	0.001	0.99	0.96	0.57	0.00
	2 × Standard/n	475	11	126	7.180	0.871	-0.012	0.002	0.99	0.80	0.01	0.00
	Standard/n	430	18	164	7.535	0.914	-0.021	0.002	0.90	0.05	0.00	0.00
Window Troughs	Standard	376	16	144	6.581	0.804	-0.004	0.001	0.99	0.96	0.51	0.00
	2 × Standard/n	330	20	186	5.887	0.657	-0.006	0.001	0.97	0.70	0.02	0.00
	Standard/n	300	10	226	6.431	0.769	-0.011	0.001	0.88	0.09	0.00	0.00

** This table is based on first site visit data from the MDE Regulatory Program (January 1991 - January 1995)

APPENDIX B

FHA Single-Family Housing Phase of the HUD Abatement Demonstration Project

APPENDIX B

FHA SINGLE-FAMILY HOUSING PHASE OF THE HUD ABATEMENT DEMONSTRATION PROJECT

The HUD Abatement Demonstration Project was performed from 1989 - 1990 to assess the costs and benefits associated with several lead-based paint abatement methods [14]. In the FHA single-family housing phase, the demonstration was conducted in HUD-owned vacant single family dwelling units. The Federal Housing Administration (FHA) held title to the houses. A total of 304 units from several different U.S. cities were tested for leaded paint, and 172 units were identified as having sufficient amounts of lead-based paint to warrant abatement. Paint abatement methods performed during the FHA phase included enclosure, encapsulation, chemical removal, removal with heat gun, removal and replacement, and abrasive removal.

Following abatement, clearance testing using individual wipe samples was conducted in 149 units. Three of the 172 units were used as pilot units and another 20 had only exterior abatement. Wipe dust-lead loading results from all clearance samples were available in the HUD Demonstration Lead-Based Paint (HUDLBP) Database maintained by Battelle [15]. Original data were obtained from Speedwell Inc., located in Boston, Massachusetts. Following the NIBS Guidelines [6], clearance dust-wipe samples were collected after the unit had been "final cleaned," but prior to recoating or priming of any surfaces [2]. Residential units passed clearance testing if all surfaces sampled resulted in dust-lead loadings below the HUD recommended standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. If these dust lead standards were not met, the study protocol required the residential unit to undergo more extensive cleaning and repeated clearance wipe sampling until the unit met the standards, for up to three iterations of cleaning and retesting. However, data from the HUDLBP Database indicated that several units underwent more than three clearance testing iterations. Note that although clearance was not attained in every unit, any failed surface was eventually sealed.

B-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

Individual dust wipe samples were collected from floors, window sills, and window troughs as part of the HUD Demonstration Project. A total of 2,854 samples were taken from 1,086 rooms in 149 residential units. Table B-1 presents the number of individual samples, work areas, and residential units that passed or failed clearance testing within each combination of component type and site visit. Approximately 73% (2,077/2,854) of the dust samples were collected during the first site visit to a residential unit. Of the 97 residential units that failed clearance on the first site visit, 95 (98%) of these residential units were revisited for a second clearance testing. This high return rate to residential units which failed is again observed in the next round as 93% (55/59) of the residential units which failed after a second site clearance testing site visit were revisited a third time. The pattern does not continue, however, since only 32% (11/34) of the sites failing clearance on the third site visit were revisited for additional clearance testing. Eventually, 111 of the 149 residential units (74%) passed clearance testing. On the first site visit, 79% (1,644/2,077) of the dust samples fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs while 68% (698/1,022) of the rooms and 35% (52/149) of the residential units passed clearance. This sharp increase in the failure rate from the percentage of individual samples that fail to the percentage of rooms and residential units that fail is attributable to the fact that if any individual sample exceeds the standard and fails clearance, then both the room and residential unit also fail clearance. This data set is particularly prone to exhibit this type of trend since, on average, there were more individual samples taken per residential unit than in any of the other data sets analyzed (13.9 per unit (2,077/149) during the first site visit).

The failure rate for individual samples during the first site visit was higher for this data set than for any other. The failure rate was highest for window trough samples at 36% (161/442), followed by floors at 19% (182/967) and window sills at 13% (90/668). The failure rate for individual samples showed an increase from the first site visit to the second site visit and again from the second visit to the third site visit. This trend indicates that units identified as a problem on the first site visit were very likely to continue to be a problem even after several attempts at clearance.

Table B-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit for the HUD Demonstration Project.

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	785	182	967	748	174	922	78	67	145
	Sill	578	90	668	576	88	664	80	46	126
	Trough	281	161	442	280	160	440	47	61	108
	All	1644	433	2077	698	324	1022	52	97	149
Second	Floor	152	82	234	141	78	219	34	36	70
	Sill	83	28	111	80	28	108	30	21	51
	Trough	88	80	168	88	80	168	29	32	61
	All	323	190	513	203	160	363	36	59	95
Third	Floor	46	34	80	43	32	75	19	16	35
	Sill	17	21	38	17	21	38	10	11	21
	Trough	35	47	82	35	45	80	12	18	30
	All	98	102	200	71	87	158	21	34	55
Fourth	Floor	12	4	16	11	4	15	5	3	8
	Sill	5	7	12	5	7	12	1	2	3
	Trough	15	6	21	15	6	21	5	2	7
	All	32	17	49	23	11	34	7	4	11
Fifth	Floor	2	2	4	2	2	4	0	2	2
	Sill	6	1	7	6	1	7	1	1	2
	Trough	4	0	4	4	0	4	1	0	1
	All	12	3	15	7	3	10	0	2	2
Total	Floor	997	304	1301	910	61	971	129	16	145
	Sill	689	147	836	674	21	695	119	14	133
	Trough	423	294	717	416	56	472	94	17	111
	All	2109	745	2854	961	125	1086	111	38	149

B-2. Objective 2: Characterization of the Distribution of the Dust-lead Loadings, Geometric Mean Dust-lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

Preliminary assessment of the data indicated that the distribution of dust-lead loading clearance sample results were highly skewed. A natural logarithm transformation was applied to the data.

For the clearance data collected in the HUD Demonstration Project, Table B-2 lists the geometric mean lead loading and the 95% confidence interval about the mean for each site visit and component type. In general, the within-home (room-to-room) variability is smaller than the between homes variability; however, all of the variance components are within a single order of magnitude of each other. Also notice that the lengths of the confidence intervals increase successively from the first site visit to the third site visit for any given component. The increase in the length of the confidence intervals is due primarily to the decrease in the number of samples used to estimate the variance components.

The geometric mean lead loadings and their 95% confidence intervals are used to compare trends between site visits for a given component tested and to compare average results between component types within a site visit. If the 95% confidence intervals on two geometric means do not overlap then these two geometric means are statistically significantly different at a level less than 0.05. A comparison across site visits shows that the geometric means for floors and window sills increase significantly from the first site visit to the second site visit, 58 $\mu g/ft^2$ to 100 $\mu g/ft^2$ and 60 $\mu g/ft^2$ to 172 $\mu g/ft^2$, respectively. The increase from the second site visit to the third site visit is not statistically significant. The geometric means from the first site visit to the third site visit for the window troughs, 393 $\mu g/ft^2$, 563 $\mu g/ft^2$, 644 $\mu g/ft^2$, are not statistically different. A comparison of the components tested within a site visit show that the floor dust-lead loadings are on average less than the window sill dust-lead loadings, which are in turn less than the window trough dust-lead loadings. Note that estimates from the fourth and fifth site visits are associated with very small sample sizes and may not be very reliable for establishing trends.

Figures B-1 and B-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures B-3 to B-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures B-6 to B-8 contain box

Table B-2. Geometric Mean and Variance Component Estimates for HUD Demo Data by Site Visit and Component Type.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$) Lower Bound	Upper Bound
First	Floor	967	922	145	58	1.15	1.05	47	70
	Sill	668	664	126	60	1.46	1.32	46	80
	Trough	442	440	108	393	1.78	1.27	274	566
Second	Floor	234	219	70	100	1.22	1.09	72	139
	Sill	111	108	51	172	1.30	1.53	105	281
	Trough	168	168	61	563	1.39	1.37	370	857
Third	Floor	80	75	35	168	0.85	1.04	114	248
	Sill	38	38	21	581	1.46	1.09	263	1283
	Trough	82	80	30	644	1.28	1.08	374	1109
Fourth	Floor	16	15	8	56	0.98	1.22	19	166
	Sill	12	12	3	438	0.78	0.45	149	1286
	Trough	21	21	7	144	2.21	0.98	22	943
Fifth	Floor	4	4	2	198	0.00	0.46	74	531
	Sill	7	7	2	304	0.00	0.47	193	478
	Trough	4	4	1	536	0.00	0.24	365	786

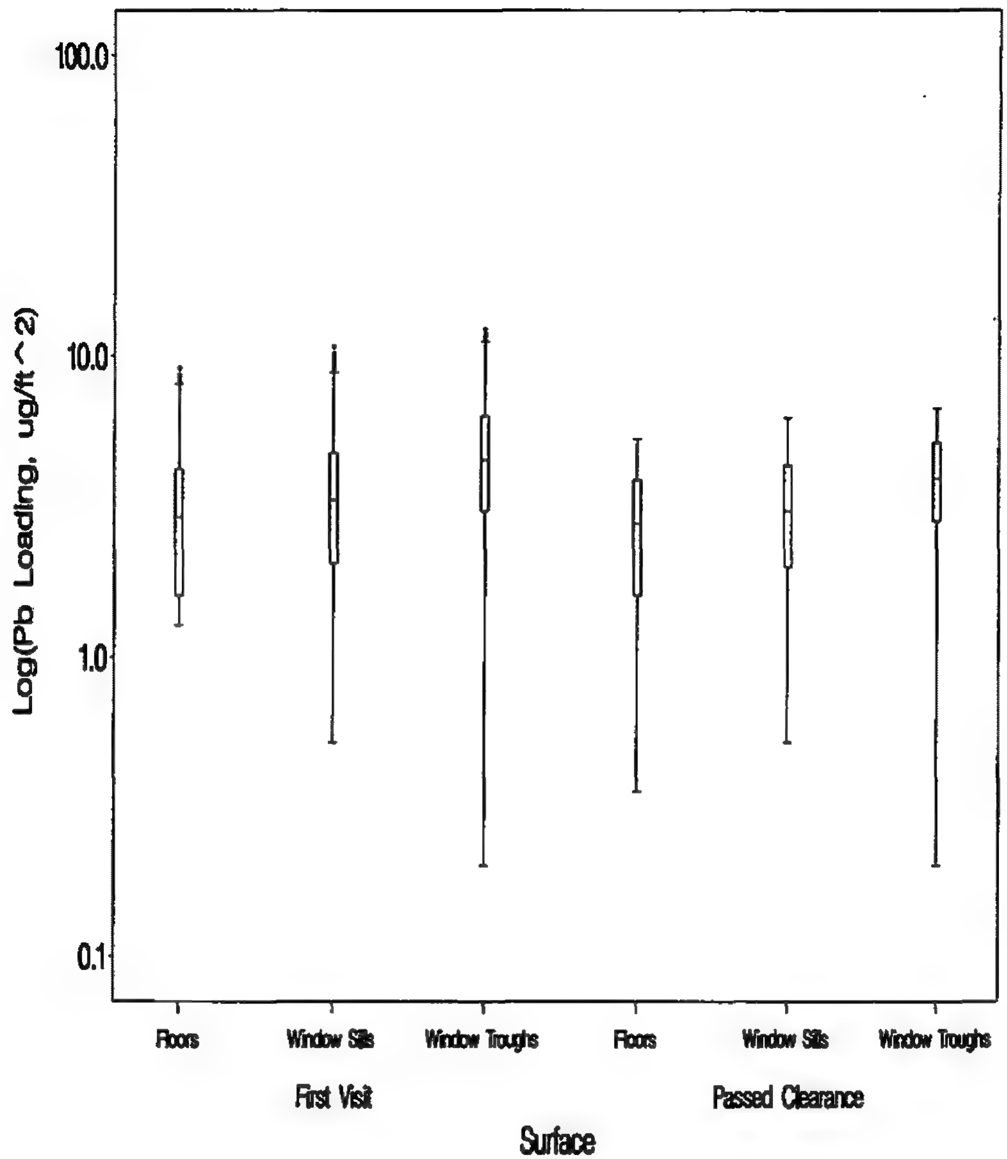

Figure B-1. Comparison of In-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.

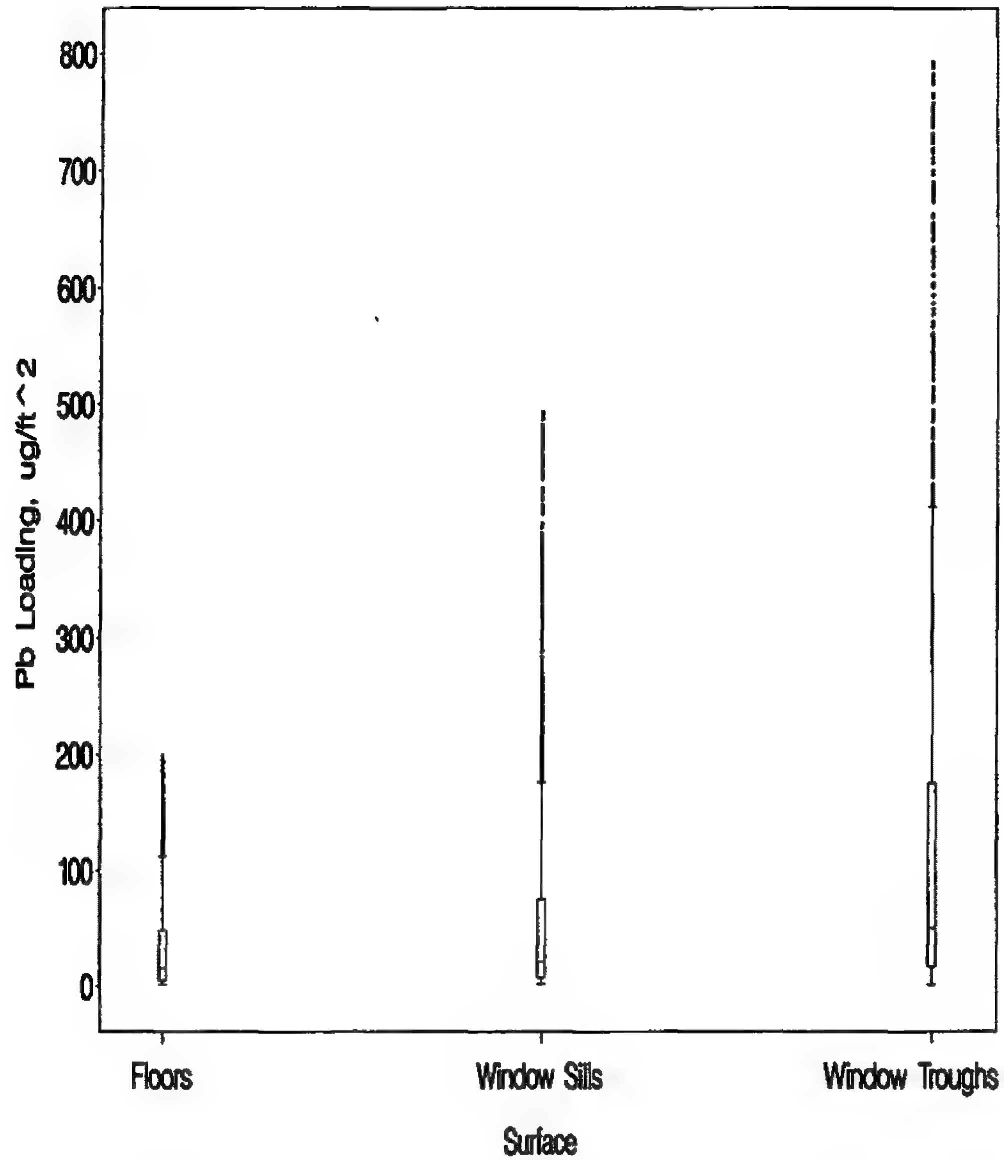

Figure B-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

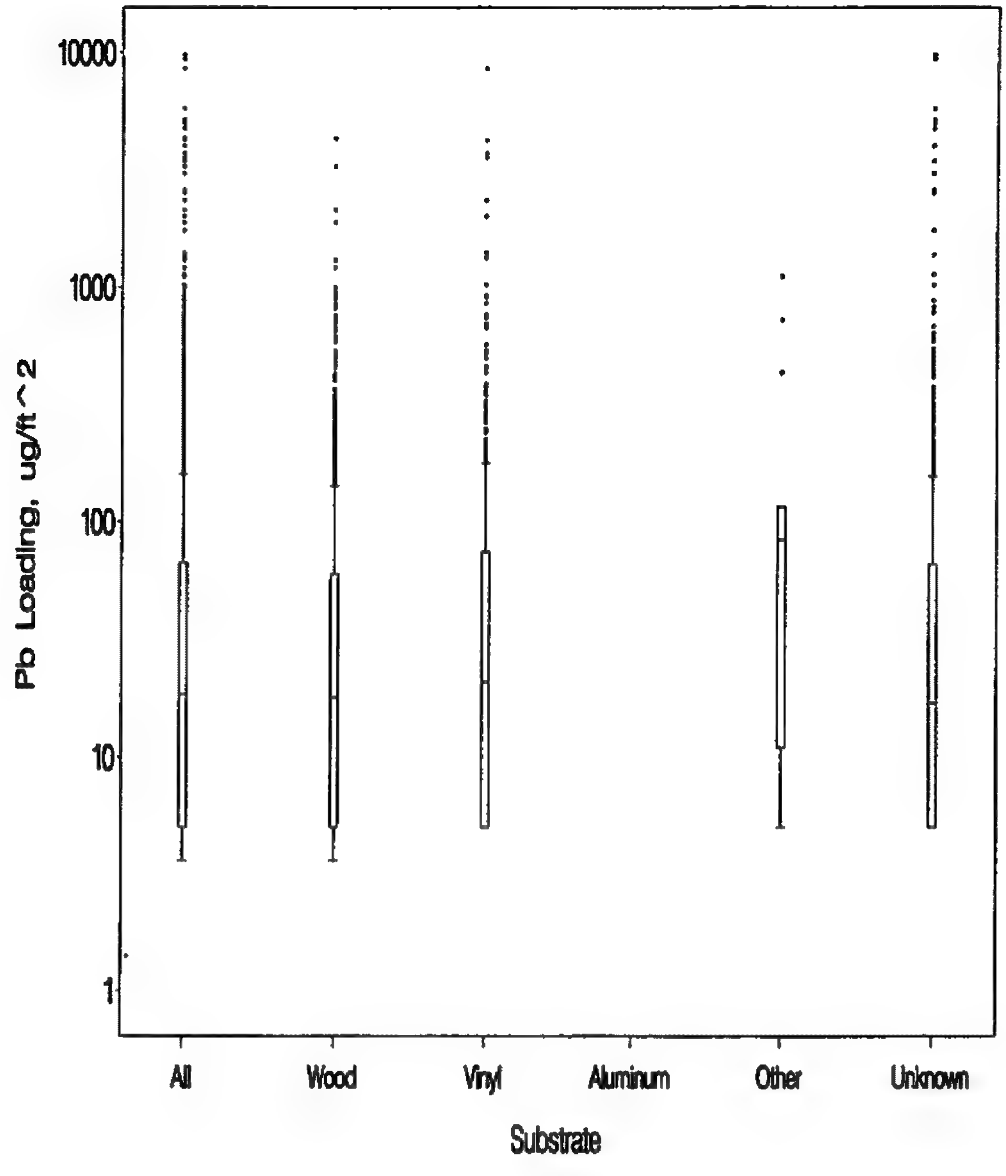

Figure B-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

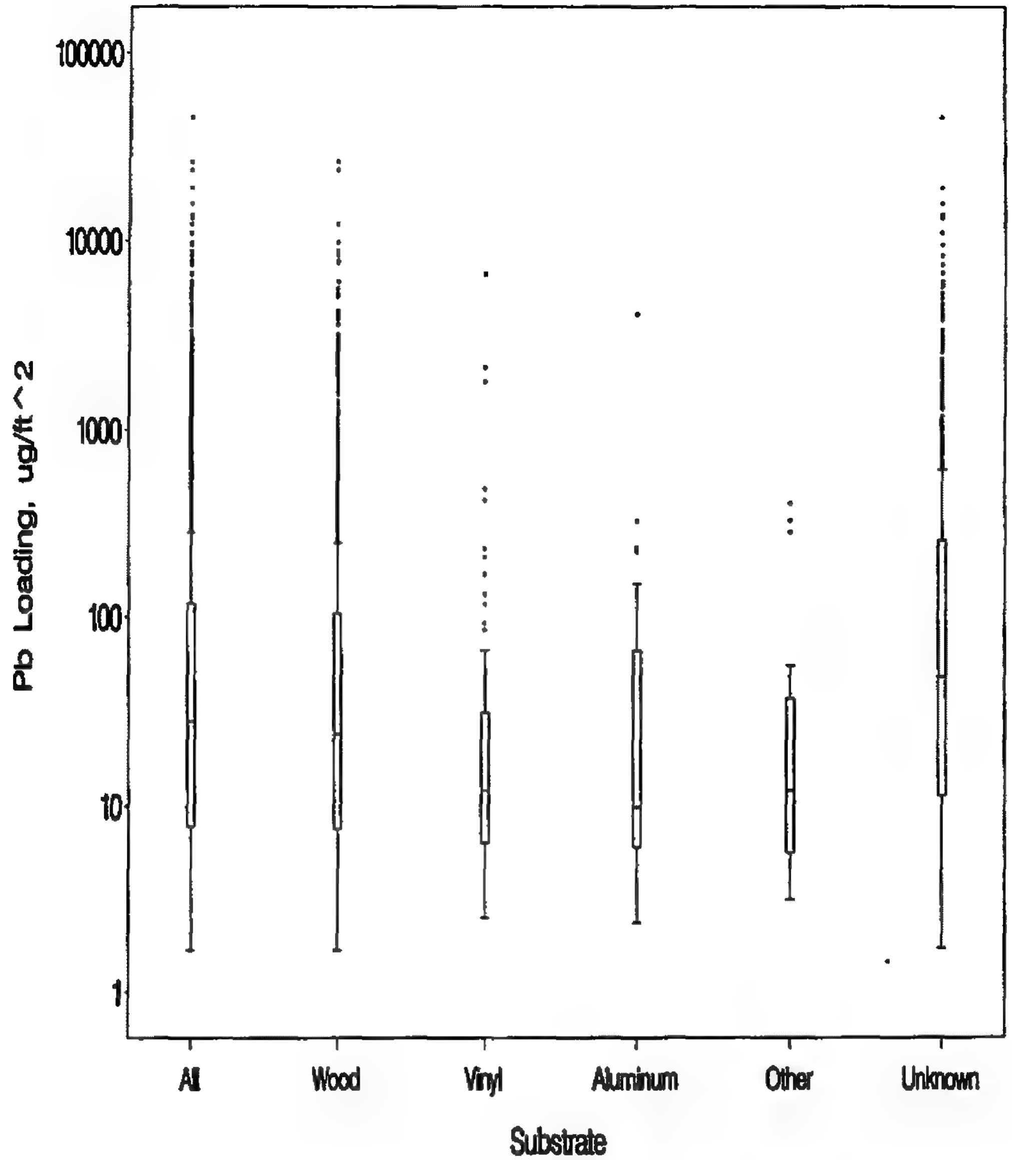

Figure B-4. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.

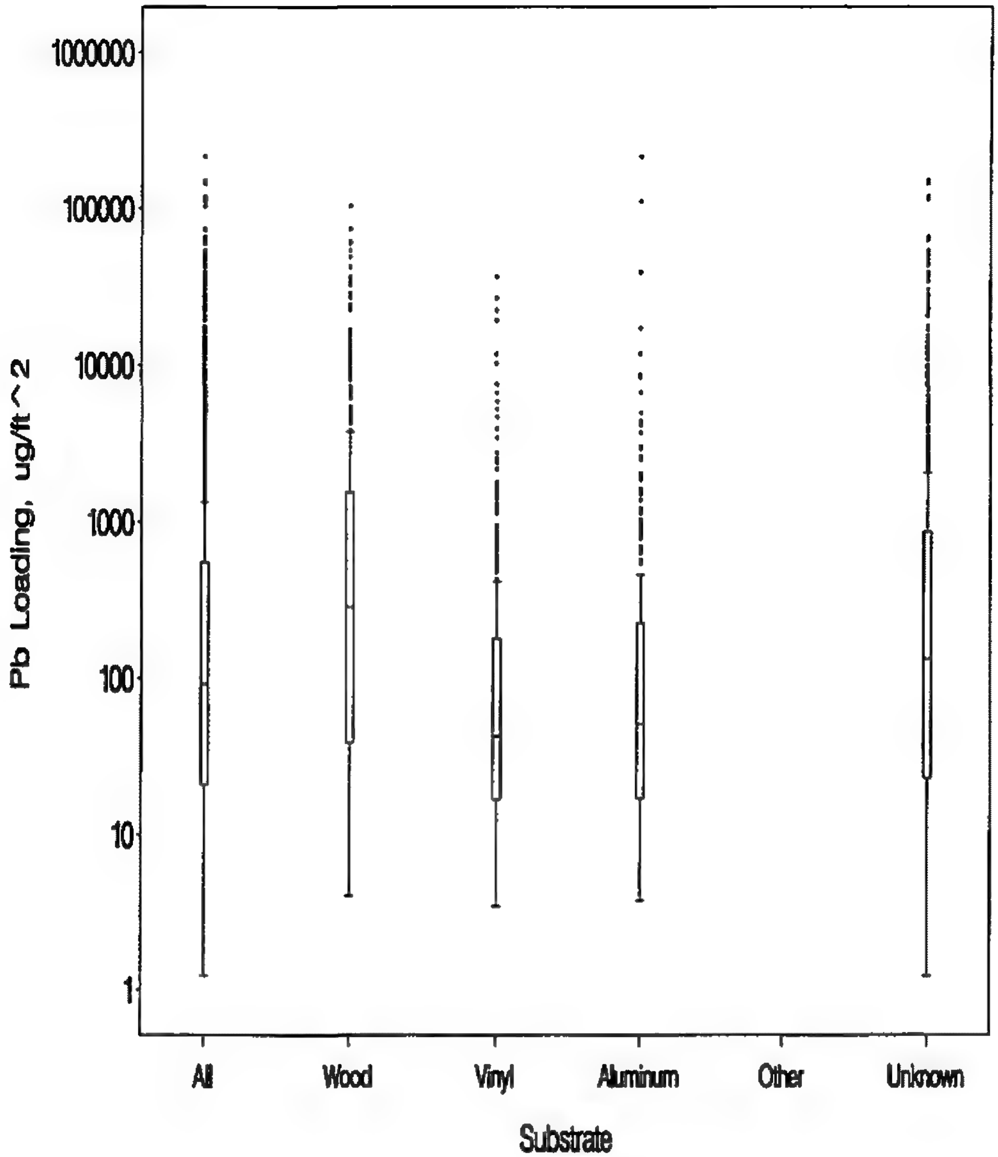

Figure B-5. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.

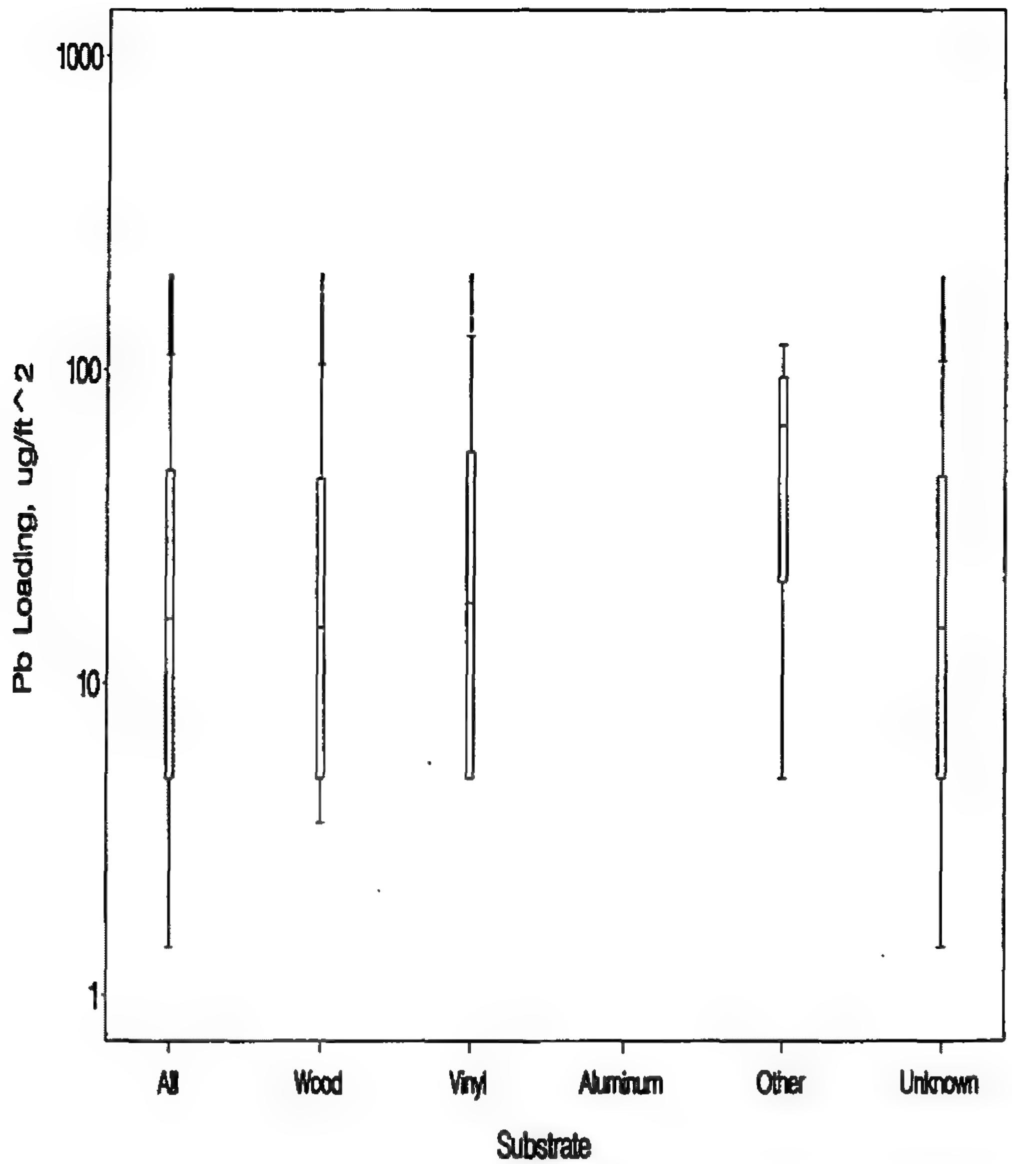

Figure B-6. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

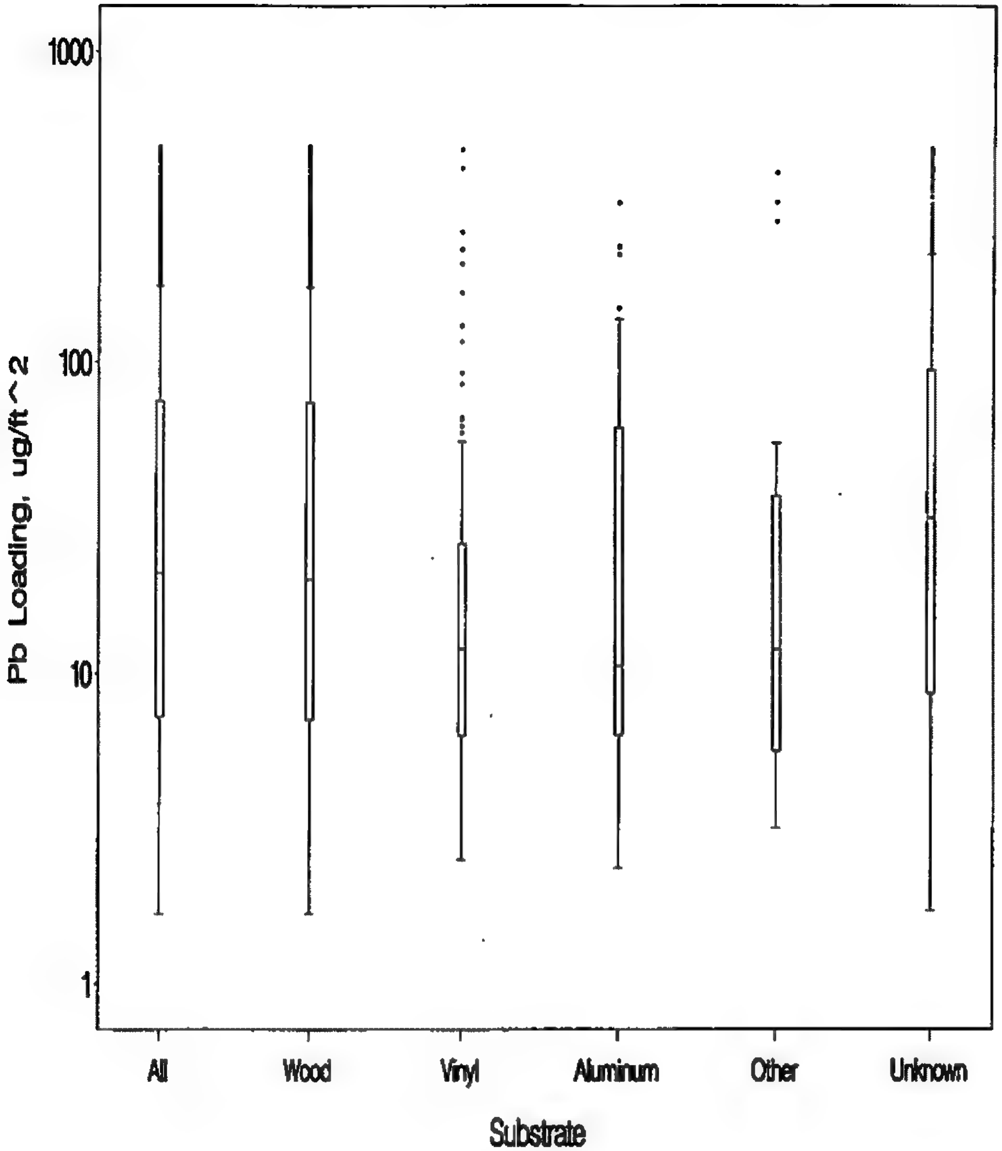

Figure B-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

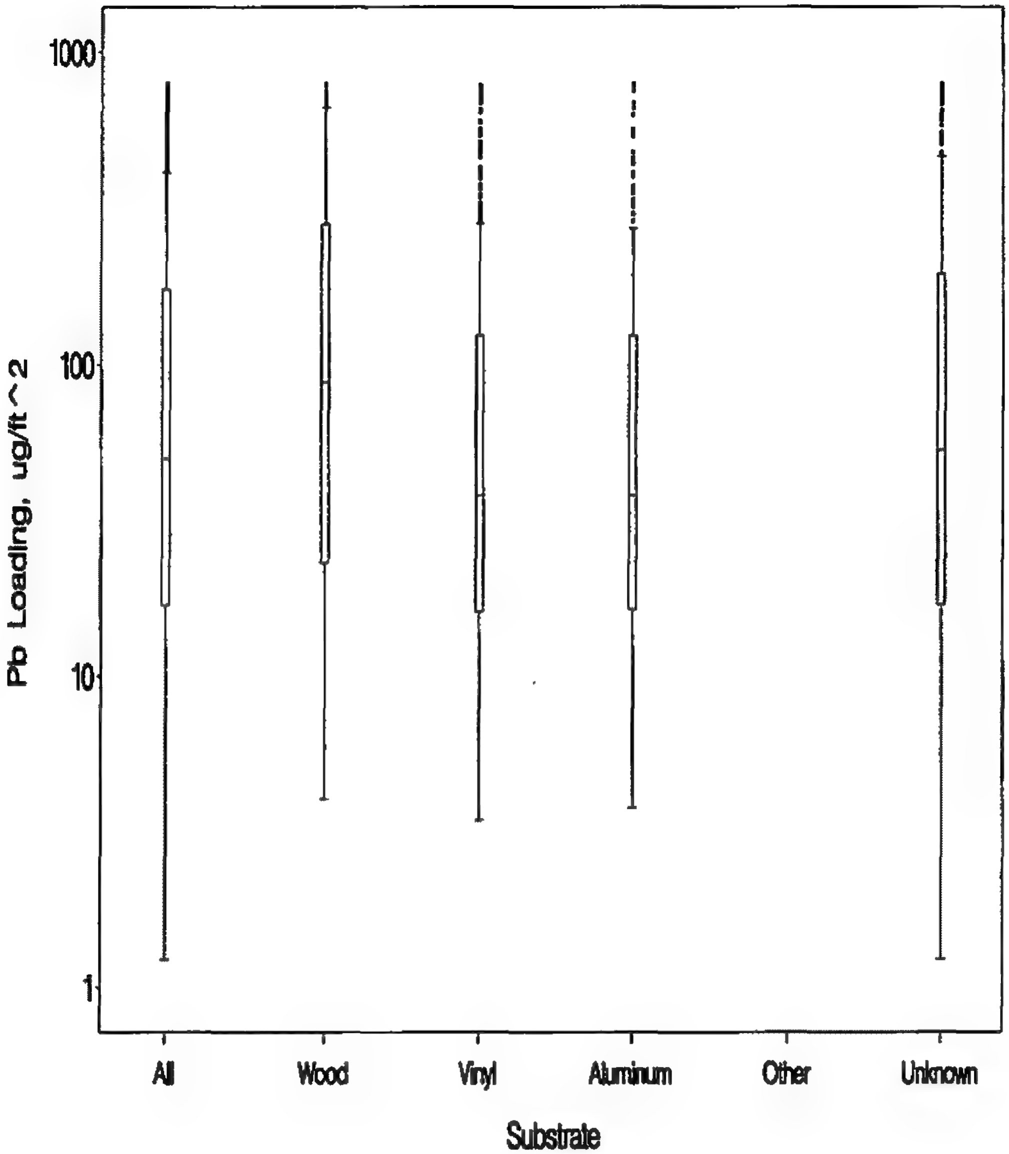

Figure B-8. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

B-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships among floor, window sill, and window trough wipe samples from within the same room are another important aspect of examining a clearance testing program. By estimating linear correlation coefficients, the strength of these relationships can be assessed. Table B-3 displays the Pearson product-moment correlation coefficients and the associated sample size for the natural logarithm transformed dust-lead loading measurements of individual floor, window sill, and window trough samples taken within the same room. The data from the first site visit show that floor samples are positively correlated with both window sill and window trough samples. The correlation between window sills and window troughs is also positive and is the highest of any observed correlation from the first site visit. All observed correlations from the first site visit are significant at the 0.01 level. The correlations from the second site visit are again all positive, but are not as strong as those observed during the first site visit. Only the correlation coefficient between floors and window sills during the second site visit is significant at the 0.05 level. The correlations from subsequent site visits are difficult to interpret because of the small number of samples from which they were estimated.

The conditional probabilities of a sample passing or failing a standard are given in Table B-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Table B-4, results from contingency table estimates and normal theory estimates are consistent. For both types of estimates and both data sets included in the analysis, the probability that one component passes clearance given that another component passes clearance ranges from 66% to 95%. The probability that a window sill sample is less than 500 $\mu g/ft^2$, given that the samples from the window troughs are less than 800 $\mu g/ft^2$, is among the highest values at 93 to 95%.

For both types of estimates and both data sets included in the analysis, the probability that one component fails clearance testing given that another component in the same room fails clearance testing ranged from 27% to 79%. The probability that a sample collected from a

window trough is greater than or equal to 800 µg/ft², given that a sample collected from the window sill is greater than or equal to 500 µg/ft², is fairly high (greater than 72%).

Table B-3. Observed Within-Room Correlation Coefficients Between Dust-Lead Loading Measurements Collected From Floors, Window Sills and Window Troughs for the HUD Demo Data.

	Observed Within Room Correlation Coefficients Between					
	Floors and Sills		Floors and Troughs		Sills and Troughs	
Site Visit	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n	$\rho_{Sills\ Troughs}$	n
First	0.39[a]	581	0.36[a]	415	0.65[a]	375
Second	0.37[b]	45	0.12	61	0.20	55
Third	-0.04	12	-0.31	14	0.59[b]	17
Fourth	0.98	4	0.75	5	0.73	9
Fifth	.	.	.	.	0.47	3

[a] Statistically significantly different from zero at the 0.01 level.
[b] Statistically significantly different from zero at the 0.05 level.

B-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

Table B-5 provides for each component type the number of residential units that were investigated by the number of individual samples that were collected. Residential units containing more than four samples from a component type were included in the estimation of multiple simulated composite sample results. From Table B-5, the number of homes with five or more samples was 125 for floors, 84 for window sills, and 47 for window troughs. Therefore, summing all the units that had five or more individual samples, approximately 86% (125/145), 67% (84/126), and 44% (47/108) of the residential units were included in the estimation of multiple simulated composite samples from floors, window sills, and window troughs, respectively. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples. The percentage of residential units with more than four individual samples of a component type was much higher in the HUD Demonstration Project than in the other sources of data considered in this analysis. This is probably attributable to the fact that the HUD Demonstration Project was research oriented.

Table B-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit.

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
P(F<200|S<500)	0.855	0.843	0.850	0.854	P(F≥200|S≥500)	0.313	0.300	0.374	0.387
P(S<500|F<200)	0.882	0.860	0.889	0.875	P(S≥500|F≥200)	0.265	0.272	0.297	0.345
P(F<200|T<800)	0.858	0.873	0.869	0.878	P(F≥200|T≥800)	0.279	0.268	0.299	0.294
P(T<800|F<200)	0.668	0.664	0.681	0.676	P(T≥800|F≥200)	0.537	0.560	0.572	0.588
P(S<500|T<800)	0.928	0.930	0.945	0.943	P(S≥500|T≥800)	0.318	0.318	0.349	0.350
P(T<800|S<500)	0.700	0.693	0.712	0.709	P(T≥800|S≥500)	0.721	0.733	0.789	0.787
P(F<200|S<500,T<800)	.	0.877	.	0.887	P(F≥200|S≥500,T≥800)	.	0.340	.	0.415
P(S<500|F<200,T<800)	.	0.935	.	0.954	P(S≥500|F≥200,T≥800)	.	0.405	.	0.495
P(T<800|F<200,S<500)	.	0.722	.	0.737	P(T≥800|F≥200,S≥500)	.	0.833	.	0.843

For each component type within a residential unit, individual clearance sample lead loading results were used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria (Standard, Standard/n, and 2×Standard/n). For each combination of component type and composite clearance criterion, each residential unit either passed clearance, failed clearance, or yielded inconclusive results. Inconclusive results were only possible for those residential units which contained more than four individual samples. From Tables B-5 and B-6, the percentage of residential units with five or more samples collected for a component that resulted in inconclusive results under the Standard/n Rule ranged from 6% (5/84) for window sills to 19% (24/125) for floor samples.

Table B-5. Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data from the HUD Demonstration Project.

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	2	8	13
2	7	5	8
3	3	21	19
4	8	8	21
5	36	23	24
6	17	23	14
7	17	22	6
8	23	9	2
9+	32	7	1
Total	145	126	108
Total with N≥5	125	84	47

The performance characteristics of each combination of component type and composite clearance criteria are presented in Table B-7 in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). By design, the sensitivity for the Standard/n Rule is always 1.00 while the specificity for this rule is estimated at 0.49 for floors, 0.88 for window sills, and 0.72 for window troughs. In contrast, the specificity of the Standard Rule is always 1.00 while the sensitivity for this rule is estimated at 0.63 for floors, 0.59 for window sills, and 0.79 for window troughs. The 2×Standard/n Rule attempts to maximize both

sensitivity and specificity. For the 2×Standard/n Rule, the values of sensitivity are higher than those calculated for the Standard Rule, while the values of specificity are higher than those calculated for the Standard/n Rule. Estimates of sensitivity and specificity in these examples are always conservative, because inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

Table B-6. Individual Sample Clearance Results Versus Simulated Composite Clearance Results Based on Data from the HUD Demonstration Project.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	78	7	80	6	47	6
	Inconclusive	0	18	0	13	0	7
	Fail	0	42	0	27	0	48
Standard/n	Pass	38	0	70	0	34	0
	Inconclusive	24	0	5	0	4	0
	Fail	16	67	5	46	9	61
2 × Standard/n	Pass	68	0	78	0	45	2
	Inconclusive	9	10	2	7	1	5
	Fail	1	57	0	39	1	54

Table B-7. Performance Characteristics of Composite Clearance Criteria Based on Data from the HUD Demonstration Project.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2 × Standard/n
Floors	Sensitivity	0.63	1.00	0.85
	Specificity	1.00	0.49	0.87
	PPV	1.00	0.81	0.98
	NPV	0.92	1.00	1.00
Window Sills	Sensitivity	0.59	1.00	0.85
	Specificity	1.00	0.88	0.98
	PPV	1.00	0.90	1.00
	NPV	0.93	1.00	1.00
Window Troughs	Sensitivity	0.79	1.00	0.89
	Specificity	1.00	0.72	0.96
	PPV	1.00	0.87	0.98
	NPV	0.89	1.00	0.96

The above performance characteristics estimated from the HUD Demonstration Project help illustrate that the three composite clearance testing criterion have different specificity and sensitivity rates. These rates correspond to the consistency between clearance decisions and the true lead hazards present in the various locations sampled (assuming the individual sample lead-loading results are representative of these lead hazards). To further characterize the performance of each of the three composite clearance criteria, the following logistic regression model was fitted to clearance data from the HUD Demonstration Project for each combination of component type and composite clearance criteria:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

For each component type, the estimated relationship between the probability of passing clearance and the maximum lead-loading is presented graphically in Figure B-9. In this figure, the solid, long-dashed, and finely-dashed lines represent the estimated relationship for the Standard, Standard/n, and 2×Standard/n Rules, respectively.

For each combination of component type and composite clearance criteria, Table B-8 provides parameter estimates and associated standard errors from fitting the logistic regression models to data from the HUD Demonstration Project. Table B-8 also presents estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2, and 4 times the associated HUD interim standard for individual samples. Results from these logistic regression models show that there is a better than 70% chance that a residential unit will pass clearance for floors and window sills under the Standard Rule for composite sampling when there is an individual sample location which has a lead-loading level that is equal to twice the HUD clearance standard. Estimates for the Standard/n Rule demonstrate this rule's high sensitivity (probability of passing is close to zero when the maximum individual sample lead loading is greater than or equal to the HUD Standard) along with a loss in specificity (probability of passing is between 0.67 and 0.90 when the maximum individual sample lead loading is equal to ½ HUD Standard). Once again, the 2×Standard/n Rule is shown to be a compromise between the Standard and Standard/n Rules. At ½ HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is nearly one, and at 2×HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is close to zero.

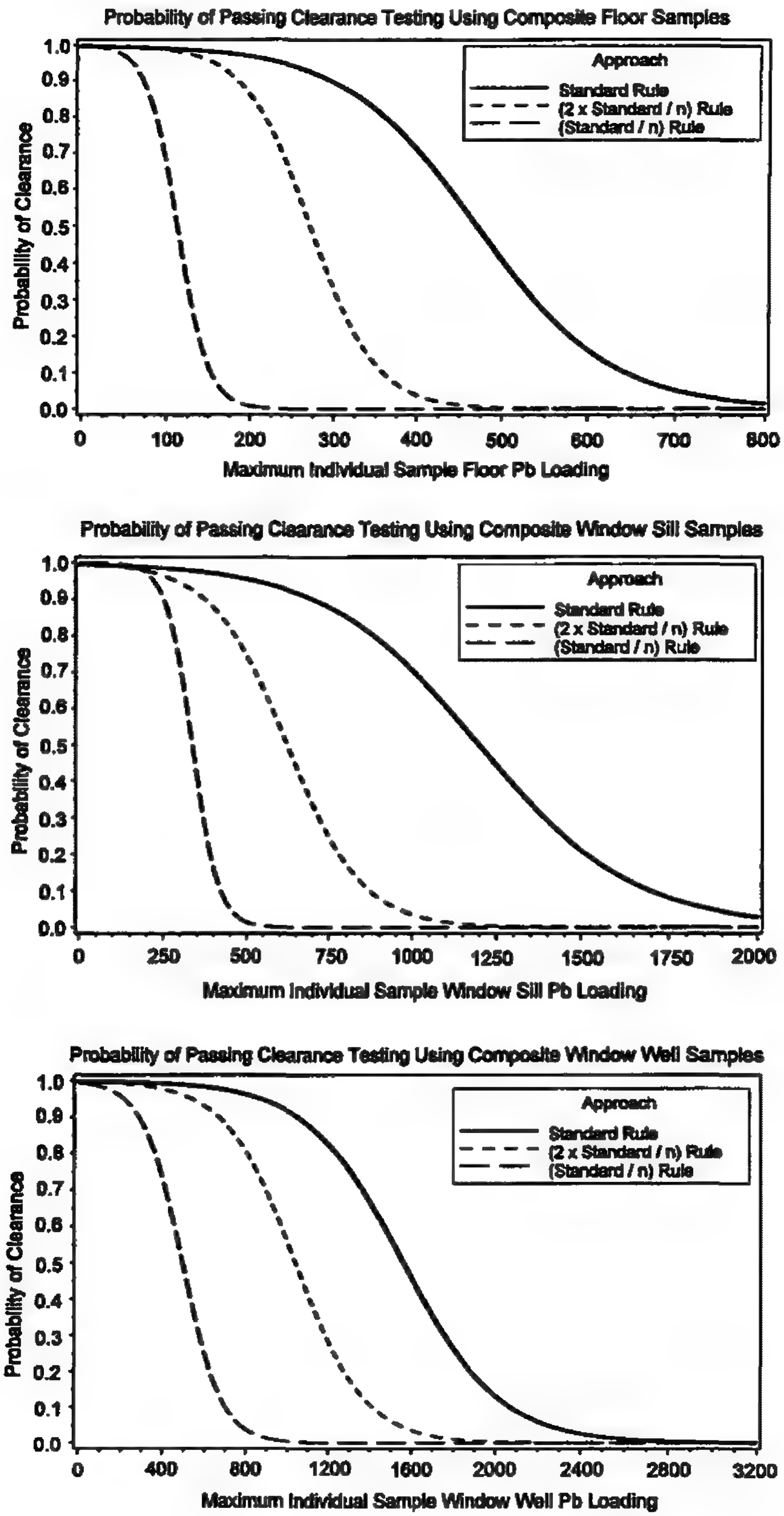

Figure B-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Result by Component Type Based on Simulated Composite Samples from the HUD Demonstration Project.

Table B-8. **Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, under Three Different Composite Sampling Decision Rules, Using HUD Demo Data.**

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance when the maximum individual sample result within a house is equal to			
		Pass	Inconclusive	Fail	β_0	s.e.(β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Floors	Standard	85	18	42	5.982	1.170	-0.013	0.003	0.99	0.97	0.71	0.02
	2 × Standard/n	68	19	58	6.907	1.416	-0.025	0.006	0.99	0.86	0.04	0.00
	Standard/n	38	24	83	6.275	1.435	-0.056	0.012	0.67	0.01	0.00	0.00
Window Sills	Standard	86	13	27	5.268	1.057	-0.004	0.001	0.99	0.96	0.70	0.03
	2 × Standard/n	78	9	39	5.452	1.149	-0.009	0.002	0.96	0.74	0.03	0.00
	Standard/n	70	5	51	8.565	2.77	-0.026	0.010	0.90	0.01	0.00	0.00
Window Troughs	Standard	53	7	48	6.713	1.883	-0.004	0.001	0.99	0.96	0.46	0.00
	2 × Standard/n	47	6	55	6.127	1.638	-0.006	0.002	0.98	0.80	0.04	0.00
	Standard/n	34	4	70	5.229	1.379	-0.011	0.003	0.73	0.04	0.00	0.00

APPENDIX C

Public Housing Administration (PHA) Phase of the HUD Abatement Demonstration Project
(Albany, Omaha, Cambridge)

APPENDIX C

PUBLIC HOUSING ADMINISTRATION (PHA) PHASE OF THE HUD ABATEMENT DEMONSTRATION PROJECT
(ALBANY, OMAHA, CAMBRIDGE)

The Public Housing Administration (PHA) Phase of the HUD Abatement Demonstration Project was performed to assess the costs and benefits associated with performing lead-based paint abatement in multifamily housing [14]. The demonstration was conducted in multi-unit apartment complexes in Cambridge, Massachusetts; Albany, New York; and Omaha, Nebraska. The project in Cambridge involved two garden apartment buildings, each with 24 residential units. Paint abatement was conducted using chemical methods for the residential units in one building, and abrasive methods were used for the residential units in the other building. In Albany, there were also two apartment buildings, each with 18 residential units. Paint abatement was performed in the first building using encapsulation and enclosure systems, and chemical stripping was used for residential units in the second apartment building. The apartment complex in Omaha consisted of brick faced townhouses, which were abated using component removal and replacement.

Following abatement, clearance testing using individual wipe samples was conducted in the residential units of each building. Wipe dust-lead loading results from all clearance samples were available in hard copy form from records collected during the study. Residential units passed clearance testing if all surfaces sampled resulted in dust-lead loadings below the HUD recommended standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs. If these dust lead standards were not met, the study protocol required the residential unit to undergo more extensive cleaning and repeated clearance wipe sampling until the unit met the standards.

The following excerpts [10-12] give detailed information on the abatement outcomes for Albany, Omaha, and Cambridge.

Albany Abatement Outcomes: Dust Lead

The interiors of all the demonstration units were wipe-tested for lead dust after the units had been deleaded and cleaned, and met visual abatement clearance standards. More wipe tests (296) were taken in Building E, where paint removal methods were widely employed, than in Building A (124), where encapsulation of lead hazards was emphasized. The Interim HUD

Guidelines required that three wipe samples be obtained in each area where on-site paint removal is used, whereas only one wipe sample was required in each area where replacement and/or encapsulation methods are employed.

All but one of 113 window sills and all but two of 98 window troughs met the wipe test clearance standard on the first attempt. The failure rate for floors on initial wipe tests was also low at 3.3% (7/202). The very low failure rate on floor wipe tests indicates the effectiveness of the cleaning, considering the polyethylene floor covering was used only on selected areas during abatement.

There were 10 cases where initial wipe test clearance standards were not achieved. Nine of these 10 cases, and five of the six units, were in Building E, where on-site paint removal methods were emphasized. All six units met the clearance criteria on the second attempt.

Omaha Abatement Outcomes: Dust Lead

The interiors of all the Demonstration dwelling units were wipe-tested for the presence of dust lead after lead-contaminated building components had been removed and the units had been cleaned and before the remainder of the modernization was started. The methods of cleaning were those prescribed in the HUD Interim Guidelines, as were the dust lead clearance standards. All 161 window troughs and 158 out of 165 window sills met the wipe test clearance standard on the first attempt. These very low failure rates may have reflected the fact that all the windows were fairly new. The failure rate for floors on the initial wipes was significantly higher at 12.9% (22/148). Sixteen of the 49 dwelling units failed to meet wipe test clearance standards at one or more interior test locations. These units were then cleaned one more time, and all of them passed when retested.

The interiors of all the Demonstration dwelling units were again wipe tested when the renovation of the buildings was complete and prior to reoccupancy. A total of 277 wipe samples were obtained and analyzed and all passed the clearance standards. On the post-abatement wipe tests, 26% of the samples had less than 25 $\mu g/ft^2$, compared to 86% on the post-renovation wipes. The post-renovation samples were not included in this analysis.

Cambridge Abatement Outcomes: Dust Lead

A visual inspection was performed to ensure that all lead-based paint had been abated in accordance with the contract specifications. This inspection was followed by a cleaning process outlined in the HUD Interim Guidelines which consisted of a thorough High Efficiency

Particulate Accumulator (HEPA) vacuuming of all surfaces, a trisodium phosphate (TSP) wash down of all surfaces, and a final HEPA vacuuming of all surfaces. The interior of all the units and selected locations in the stair systems were wipe-tested for the presence of lead dust. Generally this process called for the collection of surface dust from a horizontal surface of at least one window sill and window trough, and a one square foot area on the floor of each room or space after abatement was completed. The collection of dust was accomplished by wiping the surface with a moistened cloth wipe (a baby wipe). The wipes were then analyzed by a laboratory to determine if there was any lead present. To be acceptable, results had to be below 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs.

Over 98 percent (142 of 144) of window sills and over 95 percent (114 of 119) of the window troughs met wipe test clearance standards on the first attempt. The success rate for floors on the initial wipe clearance test was somewhat lower at 87 percent (148 of 170)[1]. Building A had a higher failure rate on initial floor wipe test (19.6 percent) than did Building B (10.2 percent), but the difference was not statistically significant. The success in achieving clearance indicated the effectiveness of the specifications and the diligence of the contractors' personnel at final cleaning.

There was a statistically significant difference between Building A and Building B when wipe test results are compared in terms of the number of attempts required to achieve wipe test clearance at each floor location. It was harder to achieve wipe test clearances on floors in Building A (where chemical stripping was used) than in Building B (where abrasive methods were used). The differences between buildings in achieving wipe test clearances on window sills and window troughs were not statistically different. All units passed clearance wipe testing.

C-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

Individual dust wipe samples were collected from Albany, Cambridge, and Omaha as part of the PHA Phase of the HUD Abatement Demonstration Project. From March 1991 through April 1993, 1433 individual dust wipe samples were collected from floors, window sills and window troughs within 821 rooms in 119 residential units. Floors were the most frequently

[1] Some difficulty was experienced in achieving wipe test clearance on concrete landings, but the problem was overcome by more frequent changes of water.

Table C-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit for the PHA Data.

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	501	57	558	443	47	490	88	31	119
	Sill	402	9	411	383	8	391	103	8	111
	Trough	364	7	371	349	7	356	105	5	110
	All	1267	73	1340	761	58	819	81	38	119
Second	Floor	40	13	53	34	9	43	24	3	27
	Sill	10	0	10	10	0	10	9	0	9
	Trough	5	2	7	5	2	7	3	2	5
	All	55	15	70	45	11	56	30	5	35
Third	Floor	5	8	13	3	6	9	0	3	3
	Trough	2	0	2	2	0	2	2	0	2
	All	7	8	15	5	6	11	2	3	5
Fourth	Floor	8	0	8	6	0	6	3	0	3
	All	8	0	8	6	0	6	3	0	3
Total	Floor	554	78	632	486	6	492	115	4	119
	Sill	412	9	421	391	1	392	110	1	111
	Trough	371	9	380	356	0	356	110	0	110
	All	1337	96	1433	814	7	821	115	4	119

sampled component (632 samples) followed by window sills (421 samples) and window troughs (380 samples). Table C-1 presents the number of individual samples, work areas, and residential units that pass or fail clearance testing within each combination of component type and site visit. Although 95% (1,267/,1340) of the dust samples collected on the first site visit fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs and 93% (761/819) of the rooms passed clearance on the first site visit, only 68% (81/119) of the residential units passed. This increase in the failure rate from the percentage of individual samples that fail to the percentage of rooms and residential units that fail is attributable to the fact that, on average, 1.6 individual samples were taken per room (1,340/819)

and 11.3 individual samples were taken per residential unit (1,340/119) during the first site visit. In general, the probability that a residential unit fails clearance increases as the number of samples collected increases.

The failure rate for individual samples taken during the first site visit was much higher for floor samples, 10% (57/558), than it was for either window sills, 2.2% (9/411) or window troughs, 1.9% (7/371). In addition, more individual floor samples, 4.7 (558/119) were collected per residential unit than for window sills, 3.7 (411/111) or for window troughs, 3.4 (371/110). Considering each component individually, 28% (31/119) of the residential units would have failed based only on the results of floor sampling. If only window sill samples were considered then 7% (8/111) of the residential units would have failed and 5% (5/110) of the units would have failed based only on the window trough samples.

C-2. Objective 2: Characterization of the Distribution of the Dust-lead Loadings, Geometric Mean Dust-lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

Preliminary assessment of the data indicated that the distribution of dust-lead loading clearance sample results was highly skewed. A natural logarithm transformation was applied to the data.

For the clearance data collected in the PHA phase of the HUD Demonstration Project, Table C-2 lists the geometric mean lead loading and the 95% confidence interval about the mean for each site visit and component type. The within-home (room-to-room) variability is larger than the between homes variability for the first site visit for all three components. The results are mixed for the second and third site visits. Notice that the lengths of the confidence intervals increase successively from the first site visit to the third site visit for any given component. The increase in the length of the confidence intervals is due primarily to the decrease in the number of samples used to estimate the variance components.

The geometric mean lead loadings and their 95% confidence intervals are used to compare trends between site visits for a given component tested and to compare average results between component types within a site visit. If the 95% confidence intervals on two geometric means do not overlap then these two geometric means are statistically significantly different at a level less than 0.05. A comparison across site visits shows that, for a given component, the geometric means are not significantly different from the first site visit to the third site visit. A comparison of the components tested within a site visit show that the floor dust-lead loadings

Table C-2. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for PHA Data.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	558	490	119	53	0.65	0.70	46	61
	Sill	411	391	111	33	0.73	0.95	28	39
	Trough	371	356	110	44	0.66	0.73	38	51
Second	Floor	53	43	27	50	1.00	0.75	32	80
	Sill	10	10	9	25	1.28	0.43	9	69
	Trough	7	7	5	122	0.80	1.31	22	680
Third	Floor	13	9	3	213	0.73	0.58	30	1510
	Sill	2	2	2	67	0.00	0.69	0	33300
Fourth	Floor	8	6	3	70	0.00	0.58	29	169

are statistically higher than the window sill dust-lead loadings for the first site visit. Significant differences are not shown between floor and window trough dust-lead loadings and between window sill and window trough dust-lead loadings for the first site visit. Also, the differences are not statistically significant for the second site visit among three components. Note that estimates from the third and fourth site visits are associated with very small sample sizes and may not be very reliable for establishing trends.

Figures C-1 and C-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures C-3 to C-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures C-6 to C-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

C-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

For the PHA Phase of the HUD Abatement Demonstration, Table C-3 displays the Pearson product-moment correlation coefficients and the associated sample size for the log lead loading measurements from the first site visit in individual floor, window sill, and window trough samples taken within the same room. The data show that floor samples are positively correlated with both window sill and window trough samples. The correlation between window sills and window troughs is also positive and is the highest of any observed correlation from the first site visit. All correlations from the first site visit are significant at the 0.01 level. The correlations observed during the first site visit for this data set are similar in magnitude to those observed for both the Maryland data set and the PHA Phase of the HUD Abatement Demonstration Project data set.

The conditional probabilities of a sample passing or failing a standard are given in Table C-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Table C-4, results from contingency table estimates and normal theory estimates are generally consistent on the left side of the table, but differ in some cases on the

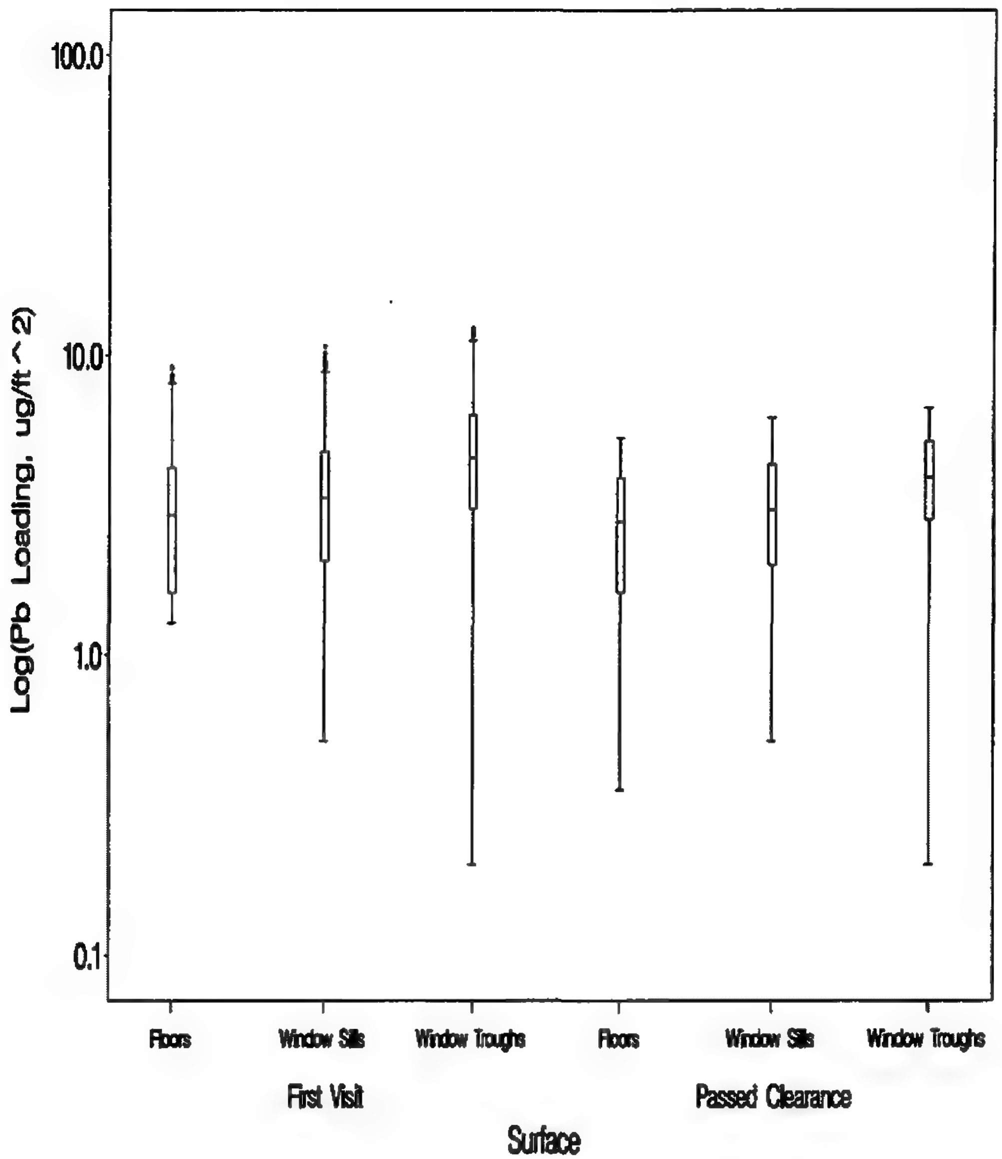

Figure C-1. **Comparison of ln-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.**

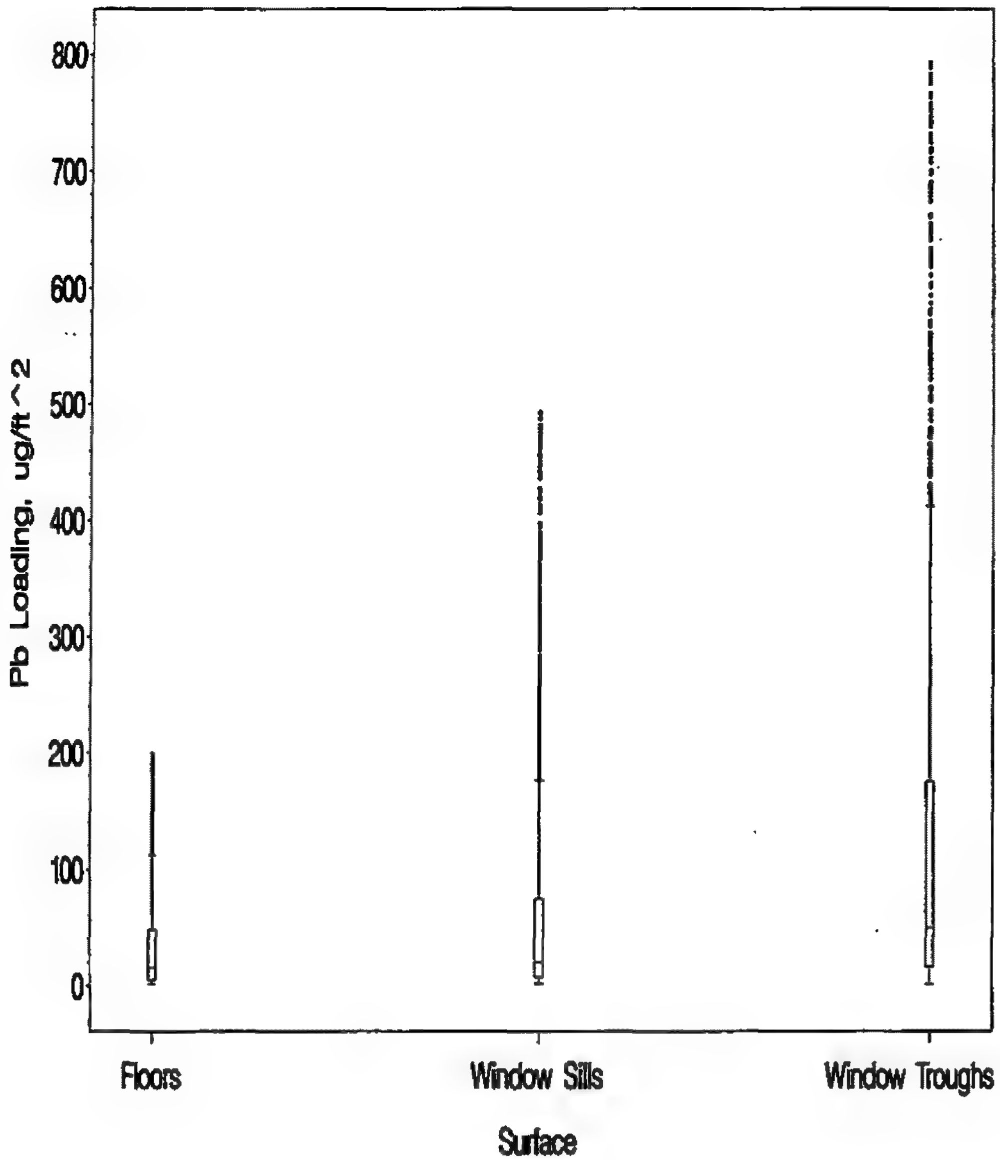

Figure C-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

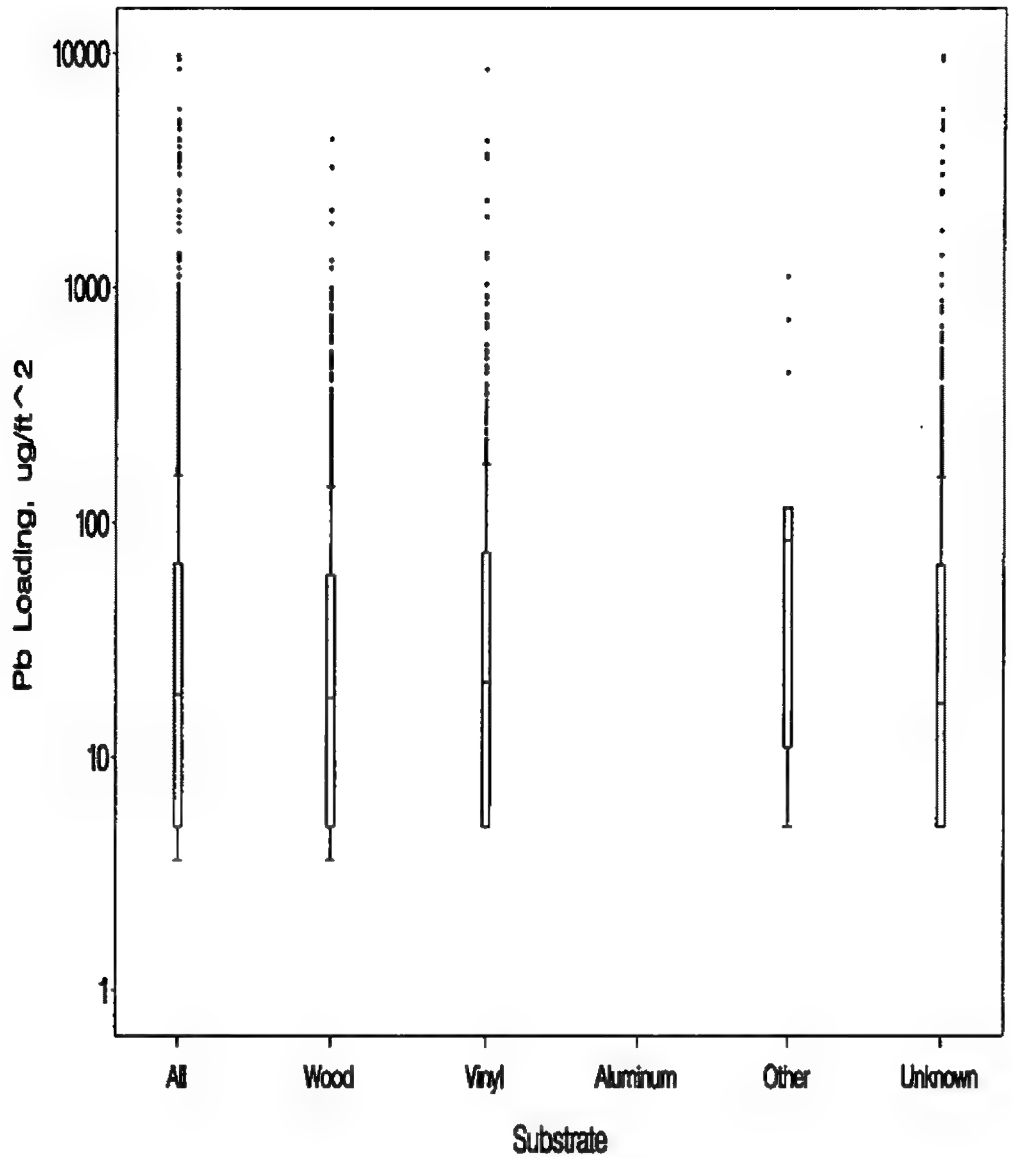

Figure C-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

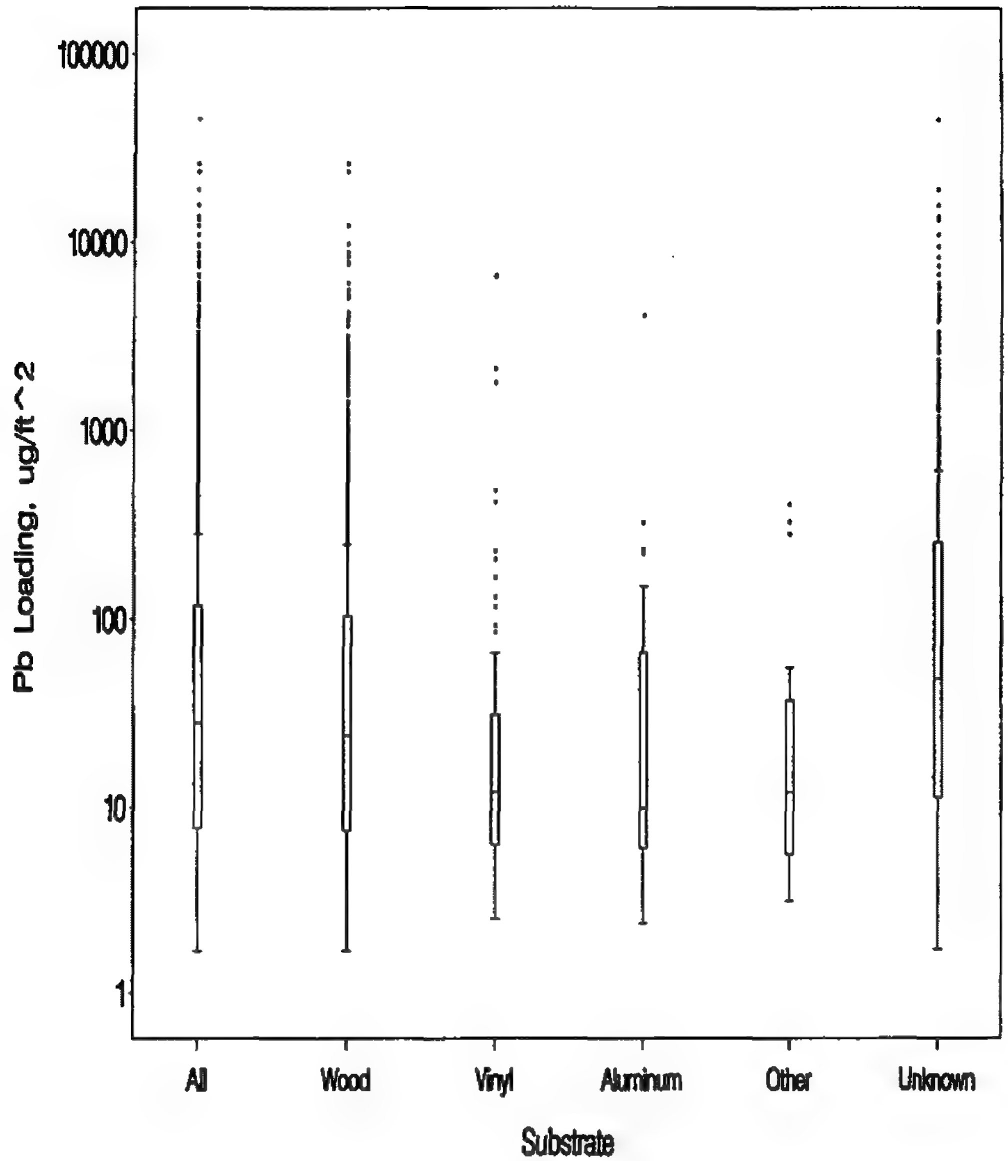

Figure C-4. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.

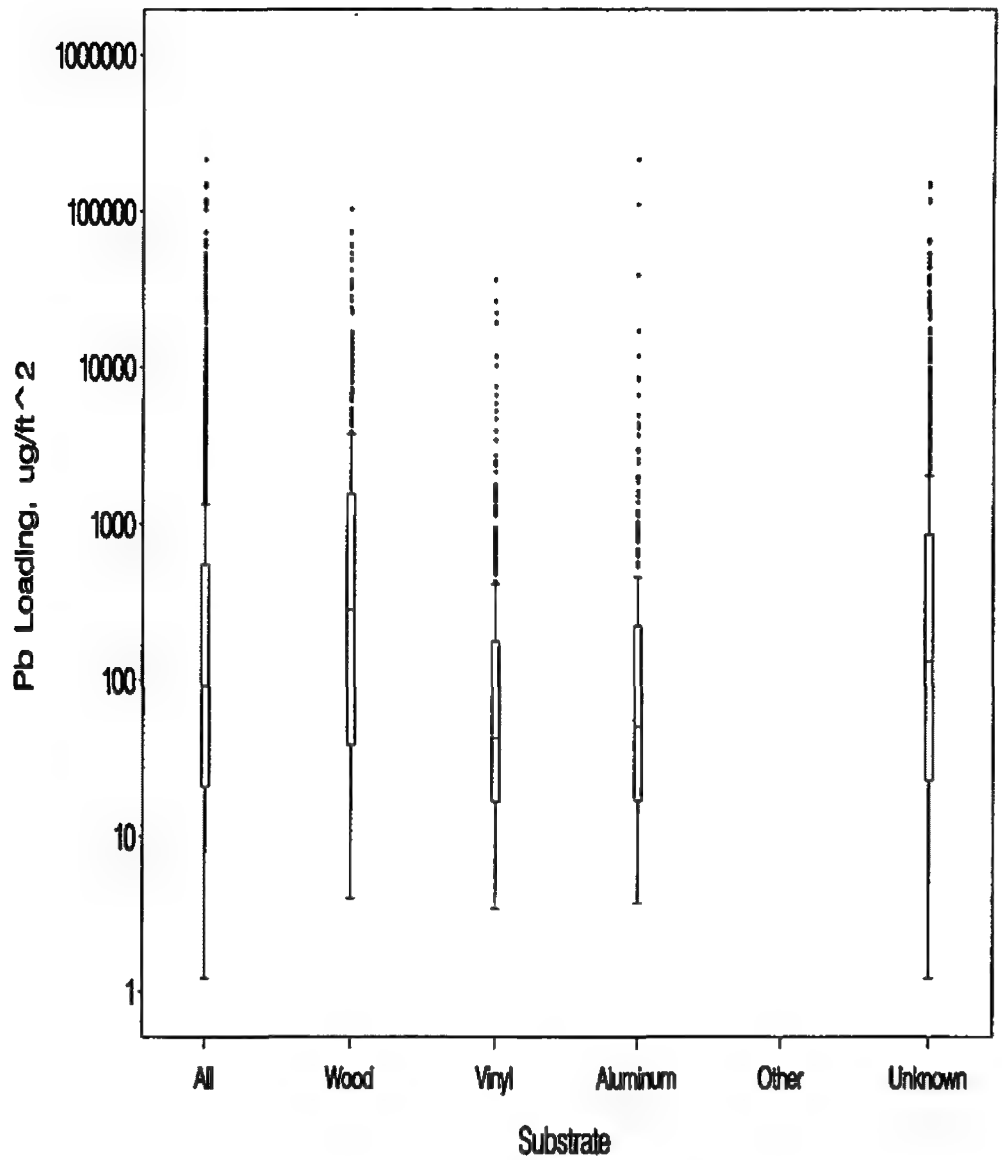

Figure C-5. **Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.**

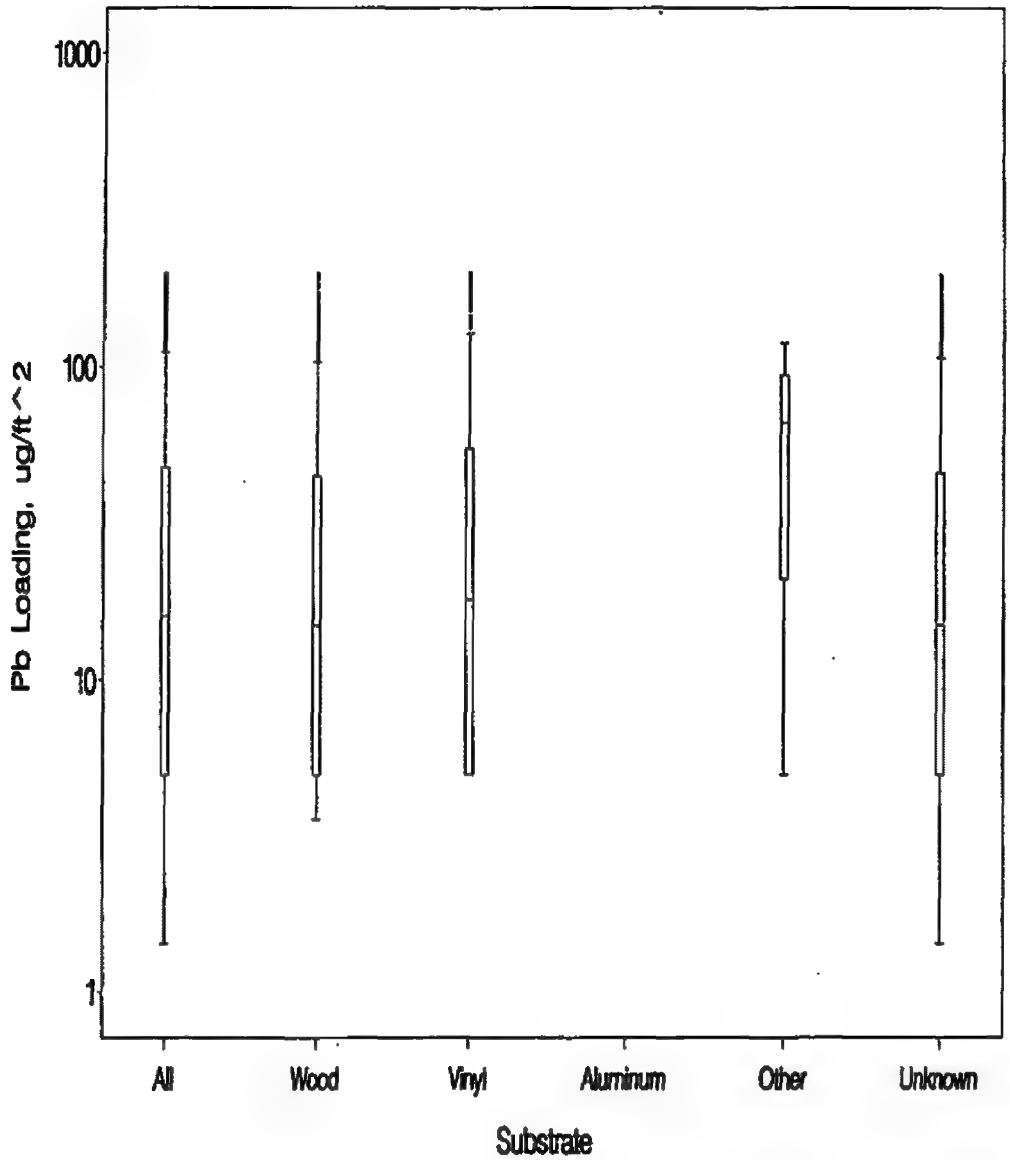

Figure C-6. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

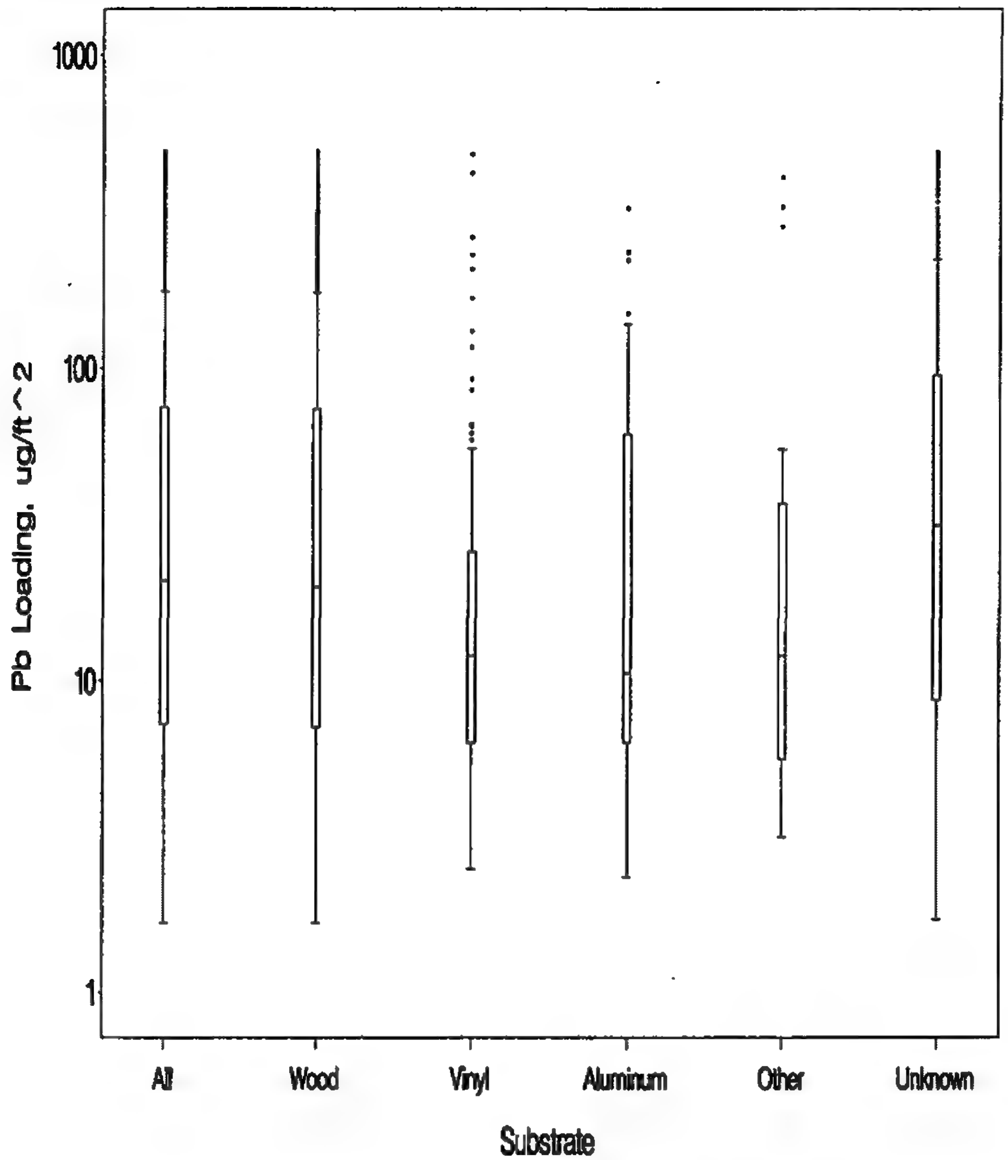

Figure C-7. **Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.**

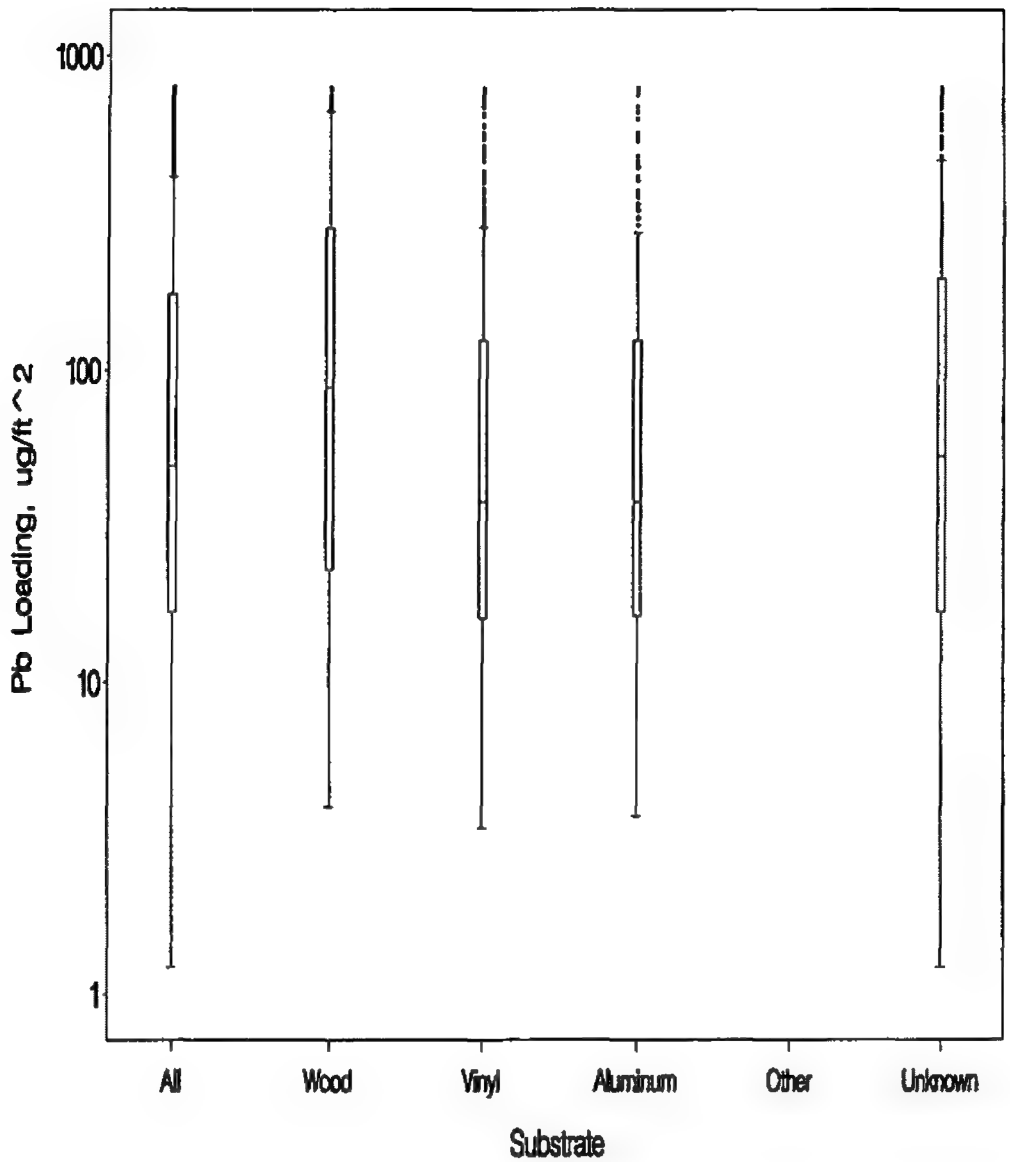

Figure C-8. **Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.**

right side. For both types of estimates and both data sets included in the analysis, the probability that one component passes clearance given that another component passes clearance is very high (greater than 93%), while the probability that one component fails clearance testing given that another component in the same room fails clearance testing is fairly low, ranging from 0% to 40%.

Table C-3. Observed Within-Room Correlation Coefficients Between Pb Loading Measurements Collected from Floors, Window Sills and Troughs for the PHA Data.

Site Visit	Observed Within-Room Correlation Coefficients Between					
	Floors and Window Sills		Floors and Window Troughs		Window Sills and Troughs	
	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n	$\rho_{Sills\ Troughs}$	n
First	0.42[a]	213	0.35[a]	192	0.58[a]	201

[a] Statistically significantly different from zero at the 0.01 level.

C-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

By combining individual sample lead loading results from each component type within a residential unit, simulated composite sample results were constructed.

Table C-5 shows the number of residential units that were investigated by the number of individual samples collected for each component type. For example, there were 25 residential units which included seven floor dust-wipe samples on the first site visit. Each residential unit which contained more than four samples from a particular component type resulted in the estimation of multiple simulated composite sample results in this analysis. For this data set, summing all the units that had five or more individual samples, approximately 45% (53/119), 29% (32/111), and 31% (34/110) of the residential units resulted in the estimation of multiple simulated composite samples from floors, window sills, and window troughs, respectively. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples.

The simulated composite samples constructed by combining the individual samples for each component type within a residential unit were used for the purpose of evaluating the three composite sample clearance criteria (Standard, Standard/n, and 2×Standard/n). For each combination of component type and composite clearance criterion, each residential unit either

Table C-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
P(F<200|S<500)	0.933	0.935	0.964	0.966	P(F≥200|S≥500)	0.000	0.000	0.277	0.4015
P(S<500|F<200)	0.989	0.994	0.998	0.999	P(S≥500|F≥200)	0.000	0.000	0.020	0.0123
P(F<200|T<800)	0.941	0.939	0.968	0.967	P(F≥200|T≥800)	0.200	0.200	0.175	0.1903
P(T<800|F<200)	0.977	0.977	0.992	0.991	P(T≥800|F≥200)	0.083	0.083	0.048	0.0560
P(S<500|T<800)	0.994	0.994	0.999	0.999	P(S≥500|T≥800)	0.000	0.000	0.043	0.0350
P(T<800|S<500)	0.975	0.973	0.991	0.990	P(T≥800|S≥500)	0.000	0.000	0.283	0.3359
P(F<200|S<500,T<800)	.	0.939	.	0.968	P(F≥200|S≥500,T≥800)	.	.	.	0.5287
P(S<500|F<200,T<800)	.	0.994	.	0.999	P(S≥500|F≥200,T≥800)	.	0.000	.	0.0973
P(T<800|F<200,S<500)	.	0.977	.	0.991	P(T≥800|F≥200,S≥500)	.	.	.	0.4423

Table C-5. Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data from the PHA Phase of the HUD Demonstration Study.

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	6	3	17
2	12	30	15
3	32	23	26
4	16	23	18
5	7	7	32
6	8	24	1
7	25	0	0
8	8	1	1
9+	5	0	0
Total	119	111	110
Total with N ≥5	53	32	34

Table C-6. Individual Sample Clearance Results Versus Simulated Composite Clearance Results Based on Data from PHA Phase of the HUD Demonstration Study.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	88	20	103	2	105	2
	Inconclusive	0	5	0	1	0	2
	Fail	0	6	0	5	0	1
Standard/n	Pass	52	0	97	0	104	0
	Inconclusive	9	0	2	0	1	0
	Fail	27	31	4	8	0	5
2 × Standard/n	Pass	75	2	100	0	105	0
	Inconclusive	8	7	2	1	0	1
	Fail	5	22	1	7	0	4

passed clearance, failed clearance, or yielded inconclusive results based on the simulated composite samples. Inconclusive results could only occur in those residential units for which more than four individual samples were collected for a component type. The many possible ways of combining five or more individual samples into multiple simulated composite samples had the potential for creating uncertainty in the decision rule for that residential unit (Table C-6). The highest inconclusive rates were observed for floors where the maximum was observed when using the 2x Standard/n Rule, which resulted in 28.3% (15/53) of the houses with more than four individual samples yielding inconclusive results. The rates for the other components ranged from 2.9% (1/34) for window troughs using the Standard/n Rule and the 2x Standard/n Rule to 9.4% (3/32) for window sills using the 2x Standard/n Rule.

The performance characteristics of each combination of component type and composite clearance criteria are presented in Table C-7 in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The sensitivity for the Standard/n Rule is always 1.00 while the specificity for this rule is estimated at 0.59 for floors, 0.94 for window sills, and 0.99 for window troughs. The specificity for the Standard Rule is always 1.00 while the sensitivity for this rule is estimated at 0.19 for floors, 0.63 for window sills, and 0.20 for window troughs. For the 2×Standard/n Rule, the values of sensitivity are higher than those calculated for the Standard Rule, while the values of specificity are higher than those calculated for the Standard/n Rule. Estimates of sensitivity and specificity in these examples are always conservative, because inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

It is evident that all three composite clearance testing criteria have different specificity and sensitivity rates associated with their application. These rates correspond to the consistency between clearance decisions based on simulated composite samples and clearance decisions based on individual samples. In order to further characterize the performance of each of the three composite clearance criterion, the following logistic regression model was fitted for each combination of component type and composite clearance criteria to describe the relationship between the probability of passing clearance and the maximum lead loading present in all of the sampling locations tested in a residential unit:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

Table C-7. Performance Characteristics of Composite Clearance Criteria Based on Data from the PHA Phase of the HUD Demonstration Study.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2 × Standard/n
Floors	Sensitivity	0.19	1.00	0.71
	Specificity	1.00	0.59	0.85
	PPV	1.00	0.53	0.82
	NPV	0.82	1.00	0.97
Window Sills	Sensitivity	0.63	1.00	0.88
	Specificity	1.00	0.94	0.97
	PPV	1.00	0.67	0.88
	NPV	0.98	1.00	1.00
Window Troughs	Sensitivity	0.20	1.00	0.80
	Specificity	1.00	0.99	1.00
	PPV	1.00	1.00	1.00
	NPV	0.98	1.00	1.00

For each component type, the estimated relationship between the probability of passing clearance and the maximum lead loading observed for the individual samples is illustrated in Figure C-9. The relationship using the Standard/n Rule for window troughs could not be estimated. It is inestimable because of the special structure of the data. For this data, all of the simulated composite samples passed when the maximum lead loading was at or below 401 $\mu g/ft^2$, and all of the simulated composite samples failed when the maximum lead loading was at or above 813 $\mu g/ft^2$ with one inconclusive composite result at 524 $\mu g/ft^2$. The estimation problem occurs because between 401 and 813 $\mu g/ft^2$ there are an infinite number of potential regression curves which can maximize the likelihood equations; hence the relationship is inestimable.

Table C-8 provides parameter estimates and associated standard errors from the logistic regression models, as well as estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2, and 4 times the associated HUD standard for individual samples. The Standard Rule's lack of sensitivity is apparent since the chance of a

residential unit passing clearance is estimated to be greater than 2/3 when there is an individual floor or sill sample location which has a lead-loading level that is equal to twice the HUD recommended clearance standard. Conversely, the estimated relationship for the Standard/n Rule demonstrates this rule's high sensitivity since the probability of passing clearance given a maximum lead loading of 2 times the HUD interim standard is always near zero. The low specificity of this rule is also apparent with estimated probability of passing clearance for floor composite samples as only 0.56 when the maximum individual sample lead loading is equal to ½ HUD Standard. Of course, because the 2×Standard/n Rule is a compromise between the Standard and Standard/n Rules, the estimated probability of passing clearance under this rule is almost always between the estimated probabilities under the other two.

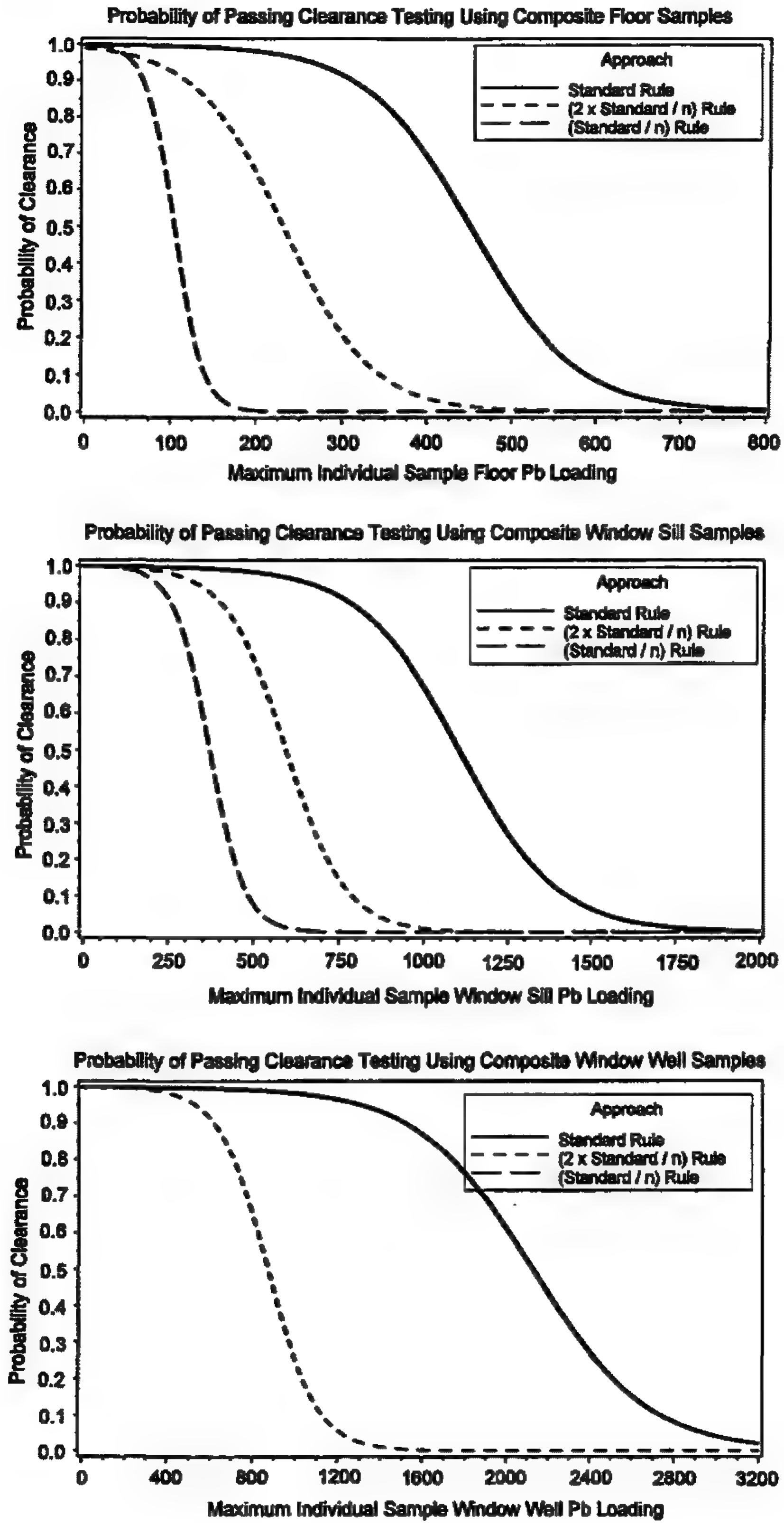

Figure C-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Result by Component Type Based on Simulated Composite Samples from the PHA Data.

Table C-8. **Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, Under Three Different Composite Sampling Decision Rules, Using the PHA Data.**

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance When the Maximum Individual Sample Result Within a House Is Equal to			
		Pass	Incon-clusive	Fail	β_0	s.e.(β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Floors	Standard	108	5	6	7.163	1.831	-0.016	0.005	1.00	0.98	0.69	0.00
	2 × Standard/n	77	15	27	4.500	0.723	-0.020	0.004	0.93	0.65	0.04	0.00
	Standard/n	52	9	58	6.338	1.307	-0.061	0.013	0.56	0.00	0.00	0.00
Window Sills	Standard	105	1	5	7.516	2.613	-0.007	0.003	1.00	0.98	0.67	0.00
	2 × Standard/n	100	3	8	6.773	1.804	-0.011	0.004	0.98	0.75	0.01	0.00
	Standard/n	97	2	12	7.144	1.908	-0.019	0.007	0.91	0.08	0.00	0.00
Window Troughs	Standard	107	2	1	7.662	3.513	-0.004	0.002	1.00	0.99	0.87	0.02
	2 × Standard/n	105	1	4	7.503	2.675	-0.009	0.003	0.98	0.65	0.00	0.00
	Standard/n	104	1	5	110.047	2.5	-0.213	0	1.00	0.00	0.00	0.00

APPENDIX D

Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program (HUD Grantee Program)

Appendix D
Summary of Background Information for the HUD Grantee Data

The overall purpose of the Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program ("HUD Grantee Program") is to measure the relative cost and effectiveness of the various methods used by State and local government grantees to reduce lead-based paint hazards in housing [17]. Although national in scope, this program is locally driven and implemented. Grantees design their own programs, including the methods of recruitment and the treatments that they carry out.

There are 14 grantees in the HUD Grantee Program, with 11 starting in FY 1992 (first round, required to participate in the Evaluation) and 3 starting in FY 1993 (second round, voluntary participation). Table D-1 summarizes the administration, sampling targets, and abatement methods used for each grantee. Program standard forms and procedures were developed by the University of Cincinnati (UC) Department of Environmental Health and National Center for Lead-Safe Housing (NCLSH). UC and NCLSH are also responsible for data analysis and reporting, training, and support of grantee data collection and recording. Data management quality control was done by UC.

Data being collected in the HUD Grantee Program are environmental, biological, demographic, housing, cost, and hazard-control information. Measurements of lead in dust, paint, soil, and blood are collected, though not all grantees collect all these measurements. Pre-intervention, immediate post-intervention (clearance results), and 6- and 12-month post-intervention data are collected. However, only selected homes (estimated 800 homes) are included in the data collection for the 24- and 36-month post-interventions.

The data available to this investigation were collected through January 1999 and were released by the University of Cincinnati in February 1999. This appendix contains summaries and analysis results for this set of HUD Grantee data.

Based on the HUD Grantee Program's Fifth Interim Report (data collected through September 1, 1997), the following bulleted list provides building characteristics, occupancy status, environmental sampling, and clearance of dwelling units in the program [13].

Table D-1. Administration, Sampling Targets, and Abatement Methods by Grantee

Grantee	Number of Subgrantees	Targeted Sample	Abatement Methods[k]
Alameda County, CA[a]	1	High risk cities, many homes with lead poisoned child	Abatement and interim control work on interior, minimal exterior work, extensive soil treatment
Baltimore, MD	1	Three target communities, two mainly investor-owned, one mainly owner-occupied. In all three, many vacant and many rowhouses	Abatement and interim controls, window replacement, no soil treatment
Boston, MA	1	Most have received an order to abate based on presence of a lead poisoned child	State regulations dictate significant abatement. No soil treatment.
California	4[b]	Older homes in low-income neighborhoods	Interior and exterior abatement, window replacement. Infrequent soil treatment.
Chicago, IL	1[c]	Selection based on report of lead poisoned child and compliance interview	Abatement and interim control work
Cleveland, OH	1	Scattered-Site Program (SSP): targets lead poisoned children Intensive Neighborhood Program (INP): less intensive and less costly remediation, contiguous houses, some previously or concurrently rehabilitated houses managed by a large non-profit agency, high rates of childhood lead poisoning in these neighborhoods	SSP: abatement and interim control work, including soil INP: contiguous houses get emphasis on education and involvement, rehab houses get additional lead remediation
Massachusetts	4[d]	Many homes under orders to abate based on presence of a lead poisoned child.	State regulations dictate significant abatement. No soil treatment.
Minnesota	3[e]	Two subgrantees target only lead poisoned children, one targets homes with deteriorated conditions	Interim control (paint stabilization and friction controls on all deteriorated LBP). Some have exteriors enclosed with vinyl siding and other coverings
New Jersey	7[f]	Concurrent renovation/ rehabilitation, many vacant homes	Most get full abatement, some get complete removal of all lead painted components

Table D-1. Continued

Grantee	Number of Subgrantees	Targeted Sample	Abatement Methods[k]
New York City, NY	1[g]	Neighborhoods with highest percentage of lead poisoning, usually multifamily (6 to 20 units), one administrator targeted newborns with deteriorated housing, other administrator enrolled houses that were in an ongoing rehabilitation program	Interim controls of deteriorated, friction or impact surfaces. No soil treatment.
Rhode Island	1[h]	Must meet Section 8 Housing Quality Standards, owner must own no more than 12 units	Abatement (window replacement and soil treatment), interim controls (correct friction surfaces and defective paint)
Vermont	1[i]	Each source has own target: lead poisoned children, non-profit developers, unsolicited applications	Developers get substantial rehabilitation, private units get less work, one neighborhood gets cleaning, rarely performs soil intervention (but does have pre-intervention soil measurements)
Wisconsin	12[j]	Each subgrantee has own criteria	Depends on subgrantee. Pre-intervention soil measurements but no soil remediation
Milwaukee	NA	Lowest income neighborhoods, lead poisoned children, projects receiving HUD rehabilitation funds, direct outreach	Cleaning and education, interim controls, abatement, housing rehabilitation, no soil treatment

(a) Four cities: Alameda, Berkeley, Emeryville, and Oakland.
(b) Four subgrantees: Los Angeles, San Francisco, San Diego, and Visalia (Central Valley).
(c) Five different neighborhoods each do their own enrollment.
(d) Four subgrantees: Brockton, Chelsea, Lawrence, and Worcester.
(e) Three subgrantees: Duluth, Minneapolis, and Saint Paul.
(f) Eleven original subgrantees, four of which withdrew from the program. Seven subgrantees are still in the program: Camden, Elizabeth, Englewood, Irvington, Jersey City, Newark, and Paterson.
(g) Two different administrating organizations for three targeted neighborhoods: Brooklyn, the Bronx, and Manhattan.
(h) 21 local offices, one administrator.
(i) Enrolled units from several sources.
(j) Not including Milwaukee. One administrator, but many decisions made locally. Twelve subgrantees: Chippewa County, Eau Claire County, Madison, Manitowoc, Oshkosh, Richland County, Rock County, Sheboygan, Superior, Wausau, West Allis, and Wisconsin Rapids.
(k) Descriptions of the lead hazard control options use the terms "abatement" and "interim control" as they are used in Title X of the 1992 Housing and Community Development Act. Abatement denotes that class of treatment that permanently remove or cover lead-based paint hazards. HUD defines permanent treatment as treatments expected to last at least 20 years. Building component removal, surface enclosure, and paint removal are common methods of abatement. Interim controls include treatments that eliminate immediate lead-based paint hazards, but do so in a manner that is not expected to last 20 years. Repainting, friction reduction on windows and doors, and cleaning are common interim control methods.

Building Characteristics

(1) Types
- Single family detached (32%)
- Single family attached (25%), rowhouses - mostly in Baltimore
- 2-4 Unit Multi-family (37%)
- > 4 Unit Multi-family (6%), 85% of NY enrollments were of this type, averaging 14 units per building

(2) Age of Housing
- Less than 1% of the enrolled buildings built after 1959.
- 90% pre-1940
- Median for Cleveland, Massachusetts, Milwaukee, Minnesota and Vermont is pre-1910
- Median for Baltimore, Chicago and Rhode Island was in 1920's
- Median for California was in 1930's

Occupancy Status
- 20% vacant prior to intervention
- Baltimore had 60% pre-intervention vacancy rate
- Vermont, NY, NJ had from 24% to 34% pre-intervention vacancy rates
- All others had below 14% pre-intervention vacancy rate

Environmental Sampling
- Dust is collected from 7-9 locations during each phase of the Evaluation.
- Single-surface dust wipe samples are collected from:
  - Floor (bare or carpeted): Interior Entry, kitchen, child's play room (or living room), youngest child's bedroom (or smallest room), next youngest child's bedroom (if present). Note that only bare floor dust samples were included in the analyses in this report.
  - Interior window sill: kitchen, youngest child's bedroom (or smallest room)
  - Window trough: child's play room (or living room), next youngest child's bedroom (if present)

Clearance of the Dwelling Units
- Program requires clearance after intervention
- Grantees followed 1990 HUD Interim Guidelines

  Floors: 200 $\mu g/ft^2$ (lowered to 100 $\mu g/ft^2$ in 1994-1995)
  Sills: 500 $\mu g/ft^2$
  Troughs: 800 $\mu g/ft^2$
- Exception:

  Floors: Grantees used 200 $\mu g/ft^2$, 100 $\mu g/ft^2$ or a locally established level
  - Cleveland, Chicago, New Jersey, New York City used 100 $\mu g/ft^2$
  - Minnesota used 80 $\mu g/ft^2$
- 28% of the dwelling units failed the initial clearance dust lead test. There is a wide variation in the clearance rates for the grantees, with rates of initial failure for units ranging from 8 to 50 %.

All dwellings in the HUD Grantee program are required to "meet clearance" after the intervention is complete. In other words, dust wipe tests must demonstrate that the amount of leaded dust on components in all treated rooms does not exceed levels designated by HUD. For the first and second rounds of the HUD Grantee Program, clearance levels were set at 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively. In 1994-1995, HUD and EPA released new guidance that lowered the clearance level on floors, from 200 $\mu g/ft^2$ to 100 $\mu g/ft^2$. Since then, HUD has allowed grantees to use either 200 $\mu g/ft^2$, 100 $\mu g/ft^2$, or a locally established level if less than 200 $\mu g/ft^2$. Five grantees used clearance levels less than 200 $\mu g/ft^2$ for floors: Cleveland, Chicago, New Jersey, and New York City used 100 $\mu g/ft^2$, while Minnesota used 80 $\mu g/ft^2$.

Analyses of the HUD Grantee data were performed separately for two groups of grantees and presented in the following sub-Appendices: D1 and D2. Sub-Appendix D1 presents analysis results from nine grantees (Alameda County, Baltimore, Boston, California, Massachusetts, Milwaukee, Rhode Island, Vermont, and Wisconsin) that used the original HUD Interim Guidelines clearance standards, i.e., 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively. Sub-Appendix D2 presents analysis results from the other five grantees (Cleveland, Chicago, New Jersey, New York City, and Minnesota) that used a lower floor dust-lead clearance standard (i.e., either 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$).

Immediately following lead hazard control intervention (within three working days), dust wipe samples were taken and tested as part of the standard HUD clearance procedure. These clearance testing results were recorded in the "Dust Sample Collection Form." If the amount of lead in dust on any tested component in a dwelling unit exceeded the clearance level, re-cleaning and re-testing of the failed surface would be performed. These re-testing clearance results were recorded in the "Clearance Dust Re-testing after Failure Form." Each retest was numbered: the first retest was recorded as Failure #1, the second as Failure #2, and so forth.

To be consistent with other data sources presented in this report, the clearance testing dust-lead data taken from the "Dust Sample Collection Form" (immediately following intervention) were labeled as "First Site Visit" data. The clearance re-testing data taken from the "Clearance Dust Re-testing after Failure Form" were labeled as "Second Site Visit" for the first retested dust clearance data (Failure #1), as "Third Site Visit" for the second retested dust clearance data (Failure #2), and so on.

Note that in the available HUD Grantee data of January, 1999, thirty-one (31) dwelling units had dust clearance re-testing results recorded in the "Clearance Dust Re-testing after Failure Form" but no clearance data shown in the "Dust Sample Collection Form." Therefore, while these 31 units were not included in the first site visit analysis, they were included in the second or third site visit analysis. Eighteen (18) of these 31 dwelling units belong to the first analysis group (grantees that used 200 $\mu g/ft^2$ as floor dust-lead clearance standard) and 13 units belong to the second analysis group (grantees used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as floor dust-lead clearance standard). There is also a case where dwelling units had records of Failure #2 but no records for Failure #1 in the "Clearance Dust Re-testing after Failure Form." Among the 113 dwelling units which had this case, 63 belong to analysis group 1 and 50 belong to analysis group 2. These dwelling units were not included in the second site visit analysis but they were included in the third site visit analysis. However, they all had first site visit data and therefore were included in the first site visit analysis.

APPENDIX D1

Grantees with Higher Floor Dust-Lead Clearance Standard in the HUD Grantee Program

APPENDIX D1

GRANTEES WITH HIGHER FLOOR DUST-LEAD CLEARANCE STANDARD IN THE HUD GRANTEE PROGRAM

Appendix D1 presents analysis results on the clearance data collected from nine grantees that used the HUD Interim Guidelines clearance standards, i.e., 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively. This group includes grantees Alameda County, Baltimore, Boston, California, Massachusetts, Milwaukee, Rhode Island, Vermont, and Wisconsin

Note that, as explained in Appendix D, 18 dwelling units did not have first site visit dust-lead clearance data and were not included in the first site visit analysis. However, since these dwelling units had other site visit data, they were included in those analyses. Sixty-three (63) dwelling units did not have second site visit data, but did have other site visit data (including first site visit data) and were included in those site analyses.

D1-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

Individual dust wipe samples were collected from floors, window sills and window troughs as part of the HUD Grantee Program. A total of 17,231 samples were taken from 11,202 rooms in 2,150 residential units from nine grantees using the higher floor dust-lead clearance standard of 200 $\mu g/ft^2$. Table D1-1 presents the number of individual samples, work areas and residential units that passed or failed clearance testing within each combination of component type and site visit. Approximately 93% (15,979/17,231) of the dust samples were collected during the first site visit to a residential unit. On the first site visit, 95% (15,139/15,979) of the dust samples fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs while 92% (9,508/10,299) of the rooms and 75% (1,608/2,132) of the residential units passed clearance. The increase in the failure rate from the percentage of individual samples that fail to the percentage of rooms and residential units that fail is attributable to the fact that if any individual sample exceeded the standard and failed clearance, then both the room and residential unit also failed clearance.

Table D1-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit from the Grantees with Higher Floor Dust-lead Clearance Standard in the HUD Grantee Program

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	7711	468	8179	7083	459	7542	1775	317	2092
	Sill	4601	197	4798	4394	196	4590	1854	177	2031
	Trough	2827	175	3002	2686	173	2859	1546	151	1697
	All	15139	840	15979	9508	791	10299	1608	524	2132
Second	Floor	550	58	608	506	54	560	289	44	333
	Sill	261	20	281	255	20	275	190	19	209
	Trough	190	12	202	188	12	200	143	12	155
	All	1001	90	1091	795	85	880	420	68	488
Third	Floor	74	11	85	68	11	79	37	11	48
	Sill	42	2	44	42	2	44	33	2	35
	Trough	17	1	18	17	1	18	15	1	16
	All	133	14	147	104	14	118	51	13	64
Fourth	Floor	10	0	10	9	0	9	9	0	9
	Sill	2	0	2	2	0	2	2	0	2
	Trough	2	0	2	2	0	2	2	0	2
	All	14	0	14	13	0	13	12	0	12
All Visits	Floor	8345	537	8882	7652	470	8122	2054	48	2102
	Sill	4906	219	5125	4683	199	4882	2004	38	2042
	Trough	3036	188	3224	2889	174	3063	1678	30	1708
	All	16287	944	17231	10396	806	11202	2050	100	2150

The failure rate for individual samples during the first site visit was at 5.7% (468/8,179) for floors, at 4.1% (197/4,798) for window sills, and at 5.8% (175/3,002) for window trough samples. The failure rate for individual floor samples showed an increase from the first site visit (5.7%, 468/8,179) to the second site visit (9.5%, 58/608) and again from the second visit to the third site visit (12.9%, 11/85). This trend is not as obvious in window sill and window trough samples.

Of the 2,132 dwelling units in Table D1-1 for which initial post-intervention clearance sampling (first site visit) data were available, 75.4% (1,608/2,132) passed on the first attempt. A

total of 15.2% (317/2,092) units had at least one floor location with a dust-lead loading above the clearance level. This failure rate was higher than that reported for window sills (8.7%, 177/2,031) or for window troughs (8.9%, 151/1,697).

D1-2. Objective 2: Characterization of the Distribution of the Dust-lead Loadings, Geometric Mean Dust-lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

Preliminary assessment of the data indicated that the distributions of dust-lead loading clearance sample results were highly skewed. Therefore, a natural logarithm transformation was applied to the data.

For the clearance data collected from nine grantees with the higher floor dust-lead clearance standard, Table D1-2 lists the geometric mean dust-lead loading, variance components (within-home variability and between-home variability associated with these loadings), and a 95% confidence interval for the geometric mean, calculated for each site visit and component type. Notice from this table that all of the variance components are within a single order of magnitude of each other. Also, the lengths of the confidence intervals increase from the first site visit to the third site visit for any given component. The increase in the length of the confidence intervals is due primarily to the decrease in the number of samples used to estimate the variance components.

The geometric mean lead loadings and their 95% confidence intervals were used to compare trends between site visits for a given component type and to compare average results between component types within a site visit. If the 95% confidence intervals on two geometric means do not overlap, then these two geometric means are statistically significantly different at a level less than 0.05. A comparison across site visits shows that the geometric means, from the first site visit to the second site visit increase significantly: 8.8 $\mu g/ft^2$, 17.6 $\mu g/ft^2$ for floors, 11.3 $\mu g/ft^2$, 33.7 $\mu g/ft^2$ for window sills, and 26.5 $\mu g/ft^2$, 45.6 $\mu g/ft^2$ for window troughs. A comparison of the components tested for the first site visit shows that the floor dust-lead loadings

Table D1-2. Geometric Mean and Variance Component Estimates for Grantees with Higher Floor Dust-lead Clearance Standard in the HUD Grantee Program

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	8179	7542	2092	8.8	1.73	1.73	8.12	9.63
	Sill	4798	4590	2031	11.3	2.03	1.84	10.21	12.58
	Trough	3002	2859	1697	26.5	1.92	1.65	23.76	29.67
Second	Floor	608	560	333	17.6	1.40	1.53	14.39	21.56
	Sill	281	275	209	33.7	1.48	1.76	25.10	45.33
	Trough	202	200	155	45.6	1.89	1.28	31.98	64.95
Third	Floor	85	79	48	29.0	0.89	1.88	17.60	47.67
	Sill	44	44	35	50.2	0.94	1.32	29.76	84.83
	Trough	18	18	16	87.8	0.00	1.14	49.52	155.63
Fourth	Floor	10	9	9	13.8	1.00	0.43	6.00	31.70
	Sill	2	2	2	115.3	0.00	0.20	18.84	705.94
	Trough	2	2	2	54.3	0.29	0.50	0.29	10147.6

were significantly less than the window sill dust-lead loadings, which were in turn less than the window trough dust-lead loadings. Note that estimates from the fourth site visit were associated with very small sample sizes and may not be reliable for establishing trends.

Figures D1-1 and D1-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures D1-3 to D1-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures D1-6 to D1-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

D1-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships in dust-lead loadings among floor, window sill, and window trough wipe samples collected from within the same room are another important aspect of examining a clearance testing program. By estimating linear correlation coefficients, the strength of these relationships can be assessed. Table D1-3 displays the Pearson product-moment correlation coefficients and associated sample sizes for the log-transformed dust-lead loading measurements of individual floor, window sill, and window trough samples taken within the same room. For the first site visit, dust-lead loadings for floor samples were significantly positively correlated (at the 0.01 level) with loadings for both window sill and window trough samples, as was the correlation between window sills and window troughs. The correlations from the second site visit were again significantly positive between floor and sill dust-lead loadings and between sill and trough dust-lead loadings. The correlation between floor and trough samples from the second site visit, however, was not significantly different from zero. The correlations from the third site visit were not statistically significant.

The conditional probabilities of a sample passing or failing a standard are given in Table D1-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Table D1-4, results from contingency table estimates and normal theory estimates are consistent on the left side of Table D1-4, but are not always consistent

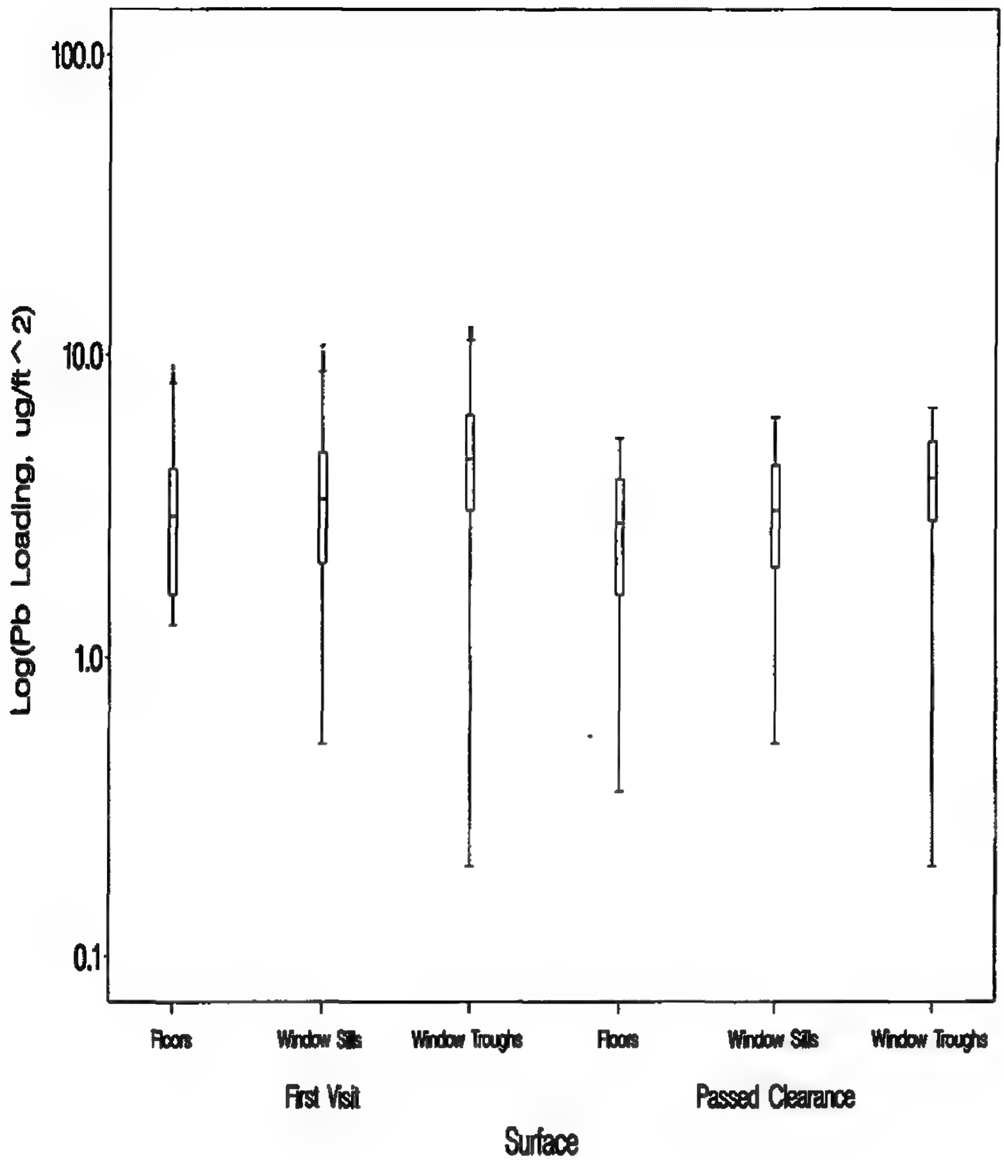

Figure D1-1. Comparison of In-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.

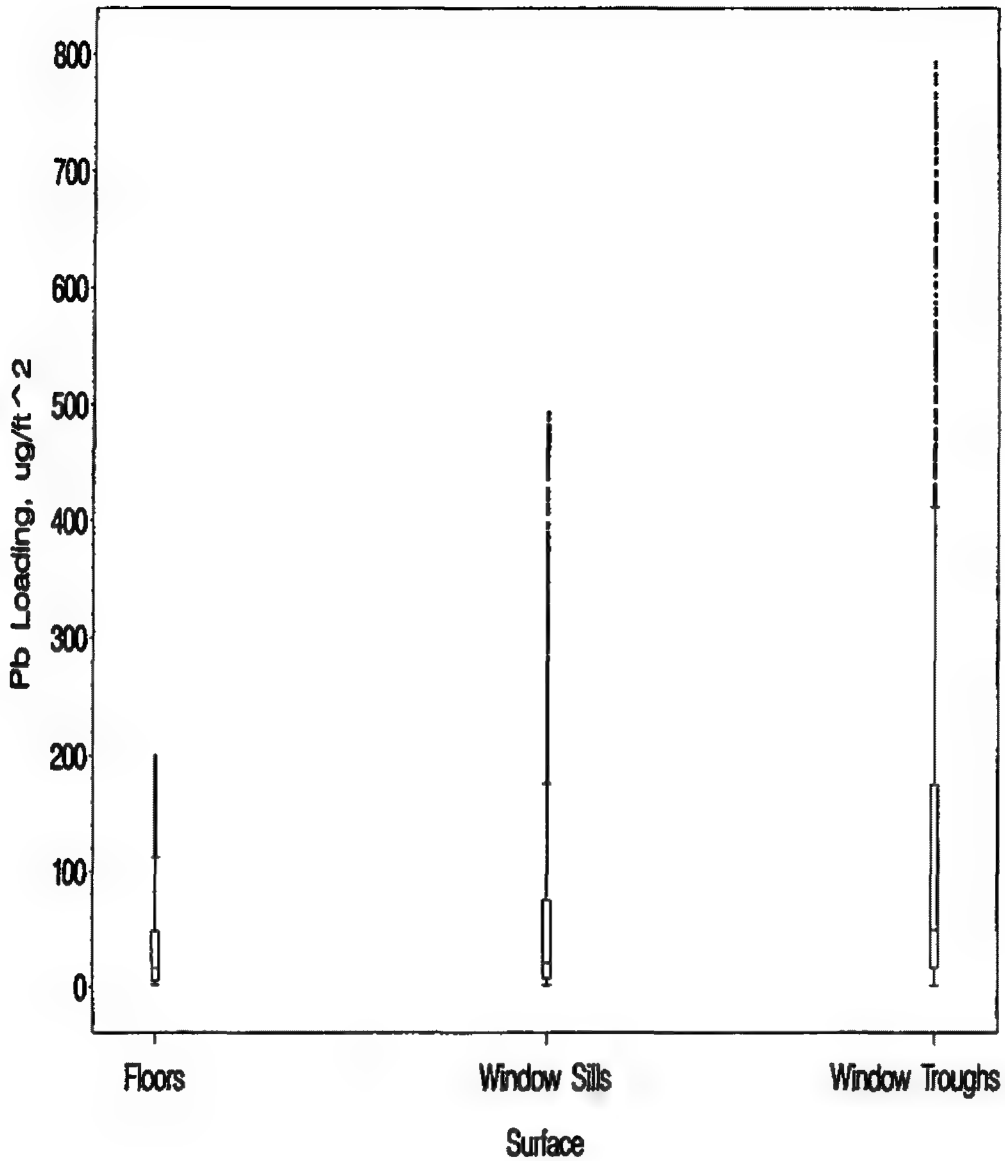

Figure D1-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

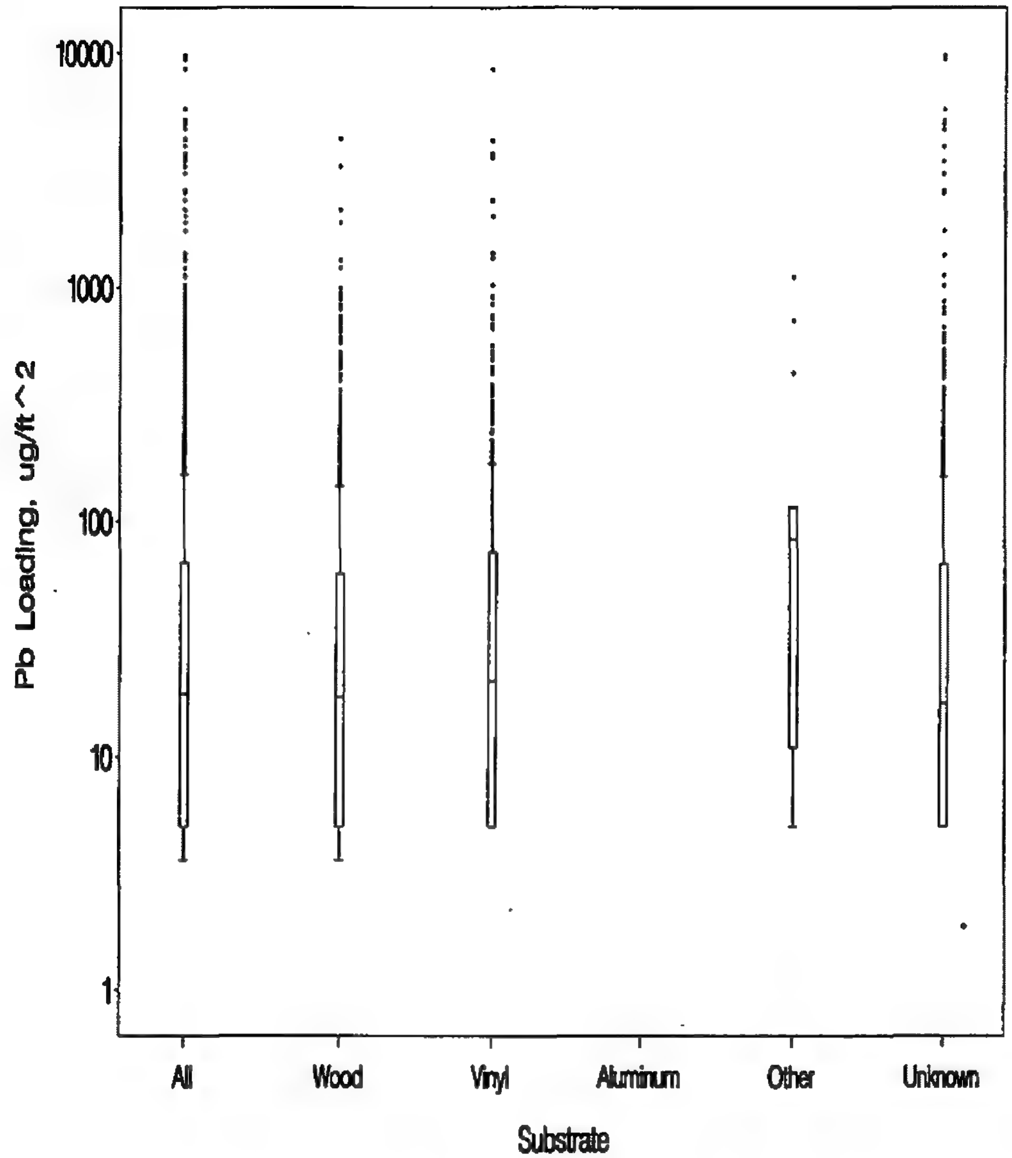

Figure D1-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

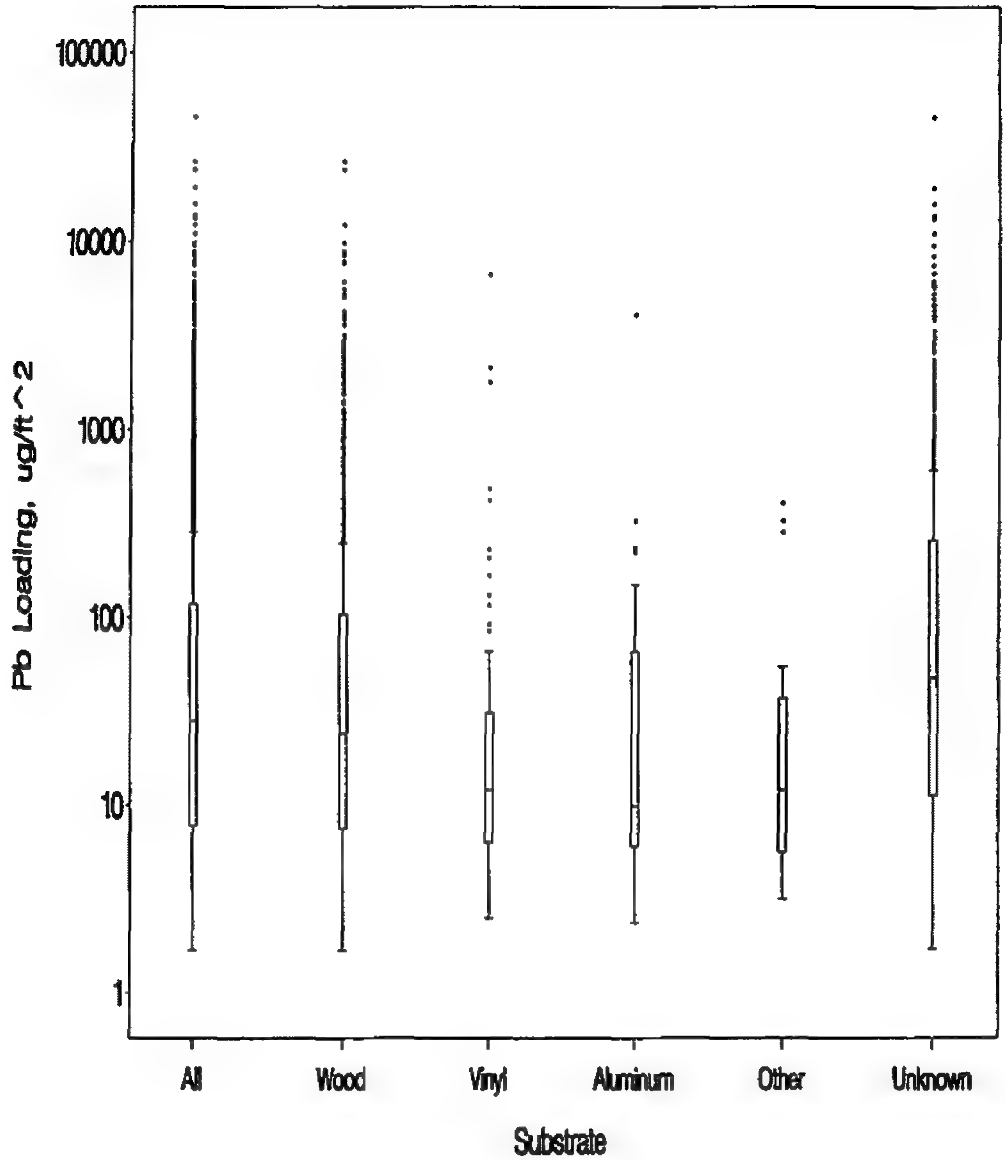

Figure D1-4. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.

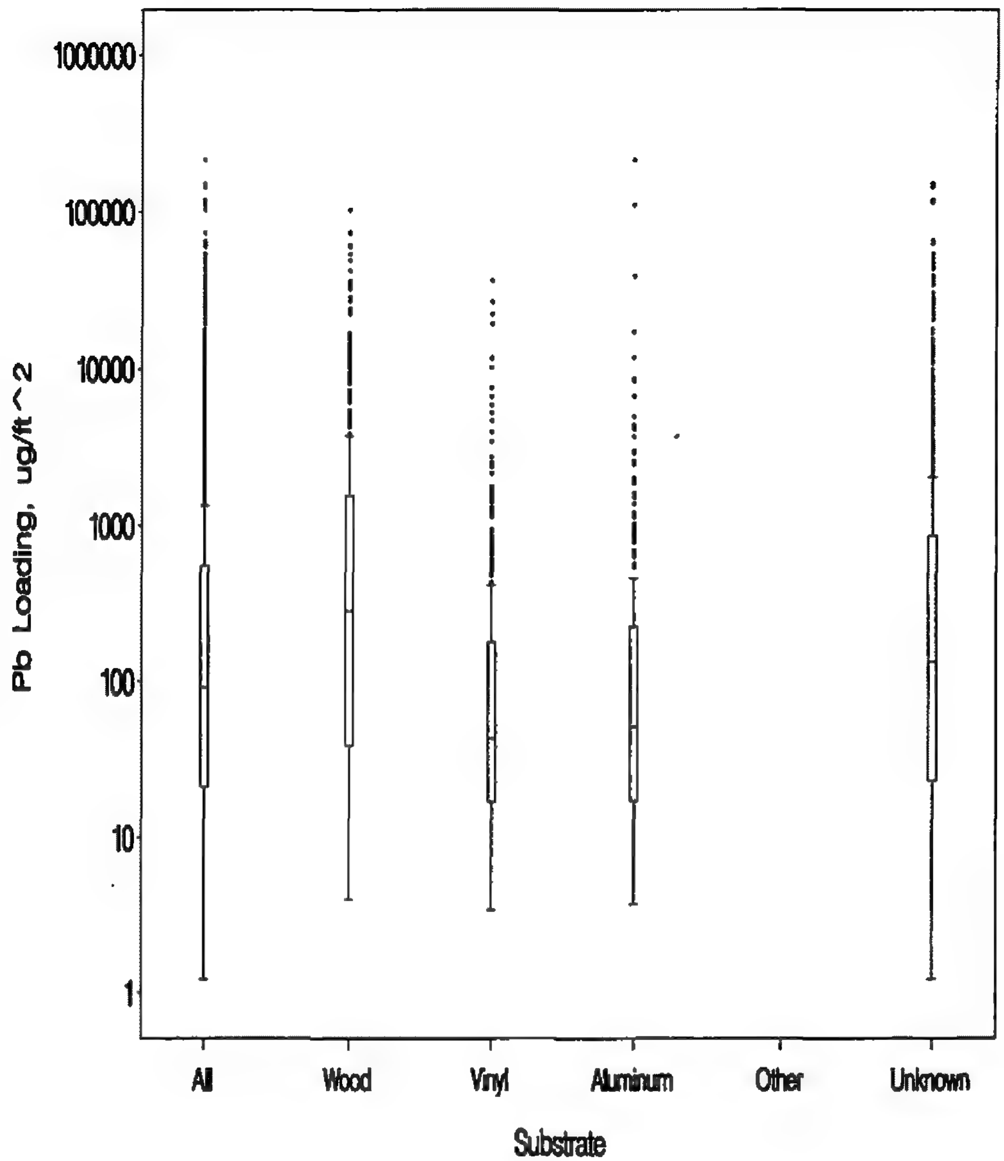

Figure D1-5. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.

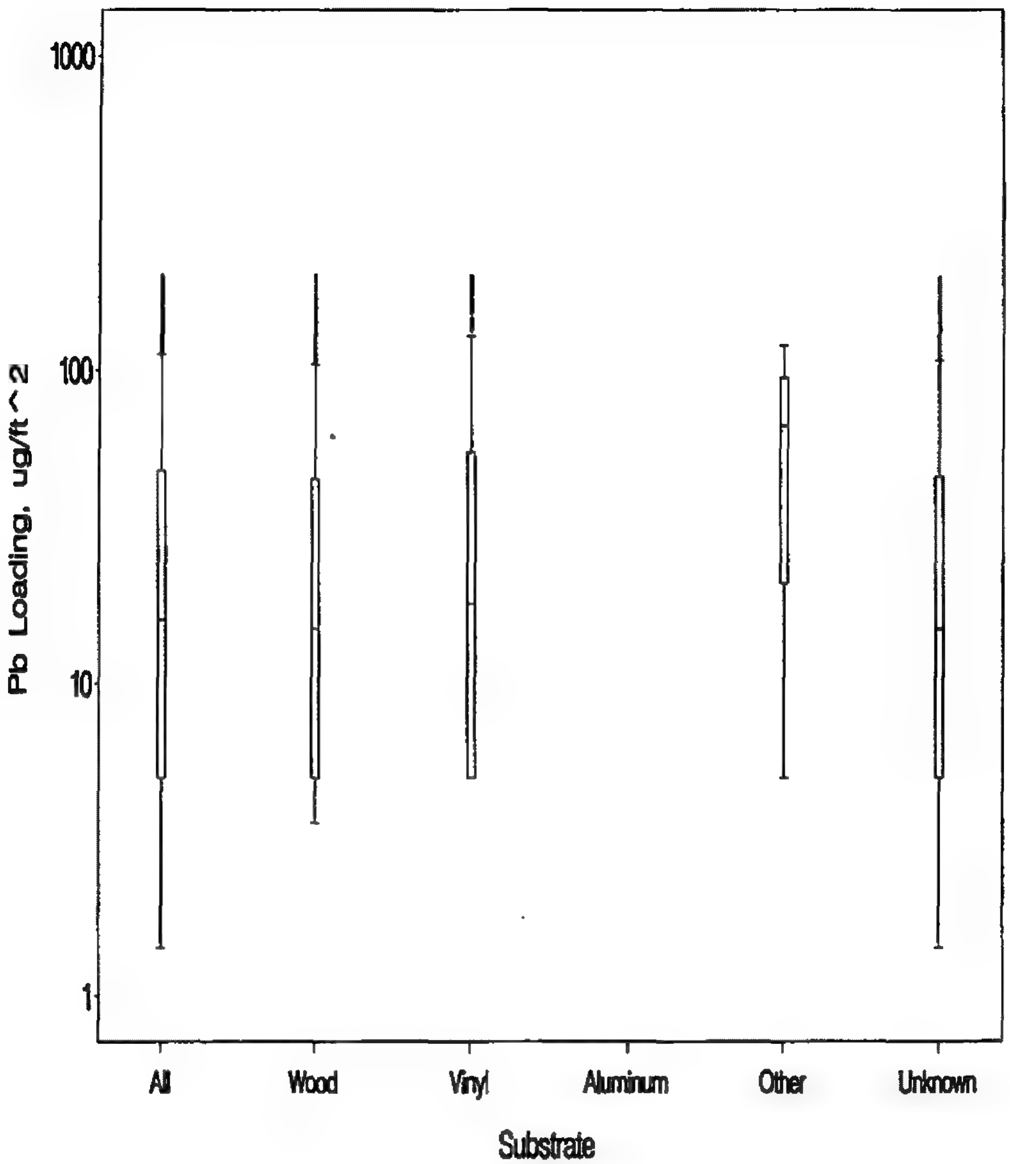

Figure D1-6. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

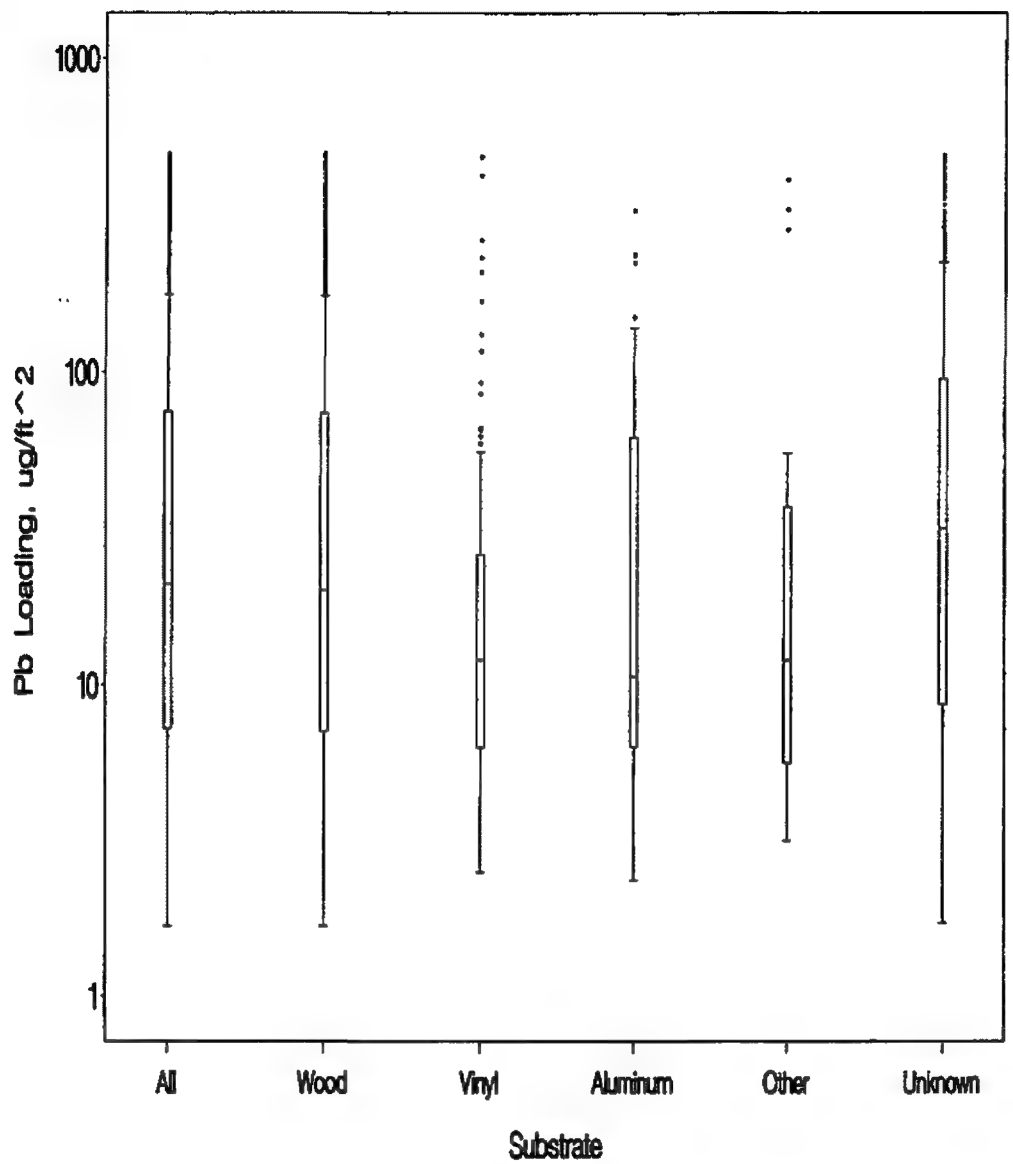

Figure D1-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

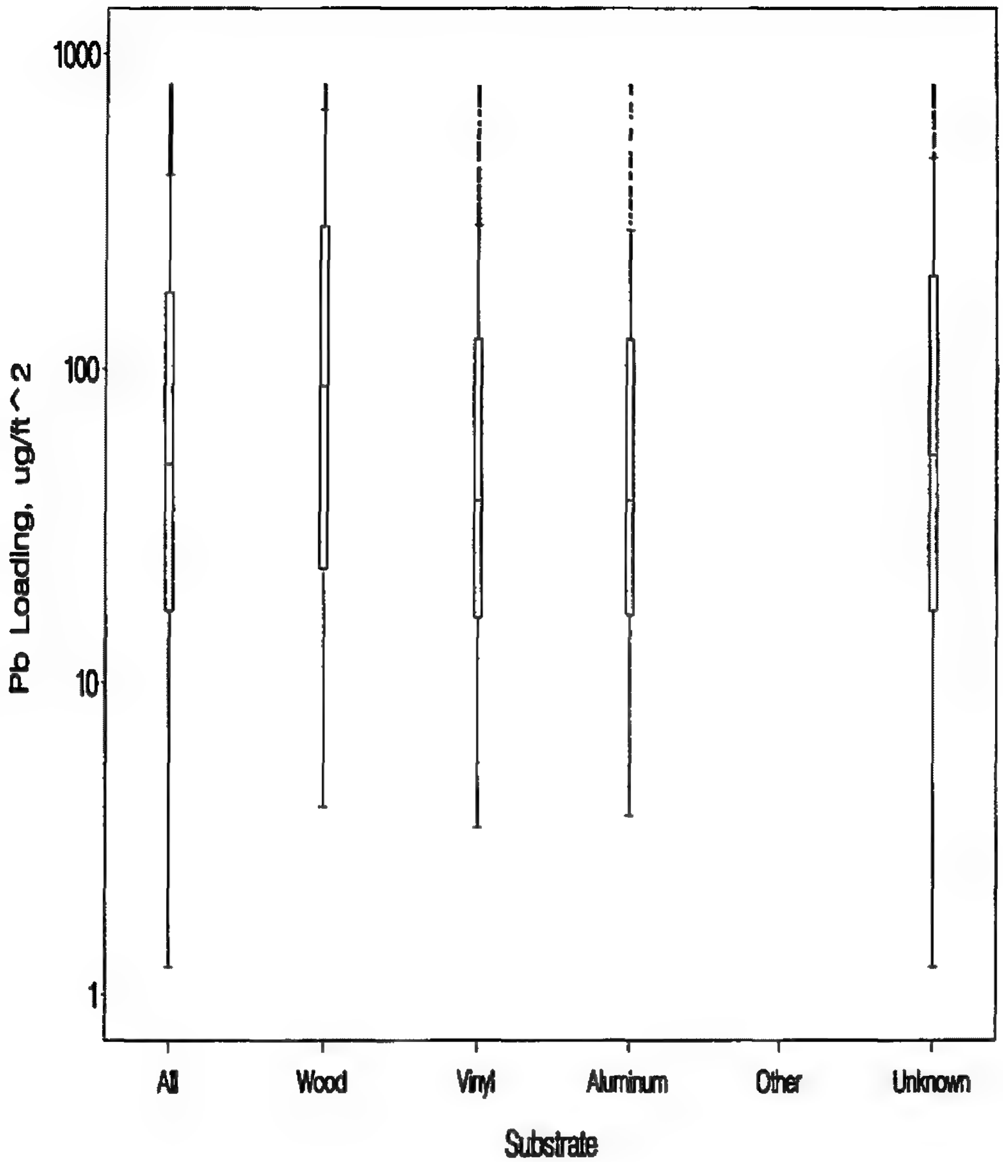

Figure D1-8. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

Table D1-3. Observed Within-Room Correlation Coefficients Between Dust-Lead Loading Measurements Collected From Floors, Window Sills and Window Troughs from the Grantees with Higher Floor Dust-lead Clearance Standard in the HUD Grantee Program.

Site Visit	Observed Within Room Correlation Coefficients Between					
	Floors and Sills		Floors and Troughs		Sills and Troughs	
	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n	$\rho_{Sills\ Troughs}$	n
First	0.46[a]	3021	0.39[a]	1558	0.39[a]	324
Second	0.30[a]	101	-0.05	51	0.70[a]	15
Third	0.31	18	-0.09	5	.	.

[a] Statistically significantly different from zero at the 0.01 level.
[b] Statistically significantly different from zero at the 0.05 level.

on the right side of the table. For both types of estimates and both data sets included in the analysis, the probability that one component passes clearance given that another component passes clearance is very high (greater than 92%), while the probability that one component fails clearance testing given that another component in the same room fails clearance testing is fairly low, ranges from 0% to 33%.

D1-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

Table D1-5 provides, for each component type, the number of residential units having a given number of samples collected from a given component type. Across component types, most of the residential units had fewer than four clearance samples collected. Data for residential units having more than four samples collected from a given component type were used in constructing multiple simulated composite samples. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples. From Table D1-5, the number of homes with five or more samples was 766 for floors, 66 for window sills, and 22 for window troughs. Therefore, data for approximately 37% (766/2,092), 3% (66/2,031), and 1% (22/1,697) of the residential units were used when constructing multiple simulated composite samples from floors, window sills, and window troughs, respectively.

Table D1-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
$P(F<200 \mid S<500)$	0.961	0.955	0.937	0.935	$P(F\geq 200 \mid S\geq 500)$	0.211	0.125	0.275	0.328
$P(S<500 \mid F<200)$	0.970	0.965	0.938	0.953	$P(S\geq 500 \mid F\geq 200)$	0.169	0.100	0.273	0.258
$P(F<200 \mid T<800)$	0.964	0.951	0.936	0.929	$P(F\geq 200 \mid T\geq 800)$	0.109	0.000	0.223	0.252
$P(T<800 \mid F<200)$	0.951	0.965	0.930	0.951	$P(T\geq 800 \mid F\geq 200)$	0.145	0.000	0.240	0.184
$P(S<500 \mid T<800)$	0.971	0.965	0.949	0.945	$P(S\geq 500 \mid T\geq 800)$	0.100	0.142	0.202	0.207
$P(T<800 \mid S<500)$	0.971	0.970	0.949	0.949	$P(T\geq 800 \mid S\geq 500)$	0.100	0.125	0.201	0.192
$P(F<200 \mid S<500, T<800)$	.	0.954	.	0.942	$P(F\geq 200 \mid S\geq 500, T\geq 800)$	.	0.000	.	0.482
$P(S<500 \mid F<200, T<800)$	.	0.969	.	0.958	$P(S\geq 500 \mid F\geq 200, T\geq 800)$	.	.	.	0.395
$P(T<800 \mid F<200, S<500)$	.	0.969	.	0.956	$P(T\geq 800 \mid F\geq 200, S\geq 500)$	.	0.000	.	0.281

Table D1-5. **Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data from the Grantees with Higher Floor Dust-lead Clearance Standard in the HUD Grantee Program.**

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	236	263	732
2	413	1068	727
3	334	501	170
4	343	133	46
5	258	41	13
6	288	20	7
7	142	2	1
8	36	2	1
9 +	42	1	0
Total	2092	2031	1697
Total with N ≥5	766	66	22

For each component type within a residential unit, the set of individual clearance sample lead loading results for the first site visit were used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria introduced in Section 5.4.2 (Standard, Standard/n, and 2×Standard/n). The construction of simulated composite samples is discussed in Section 5.4.1 For each combination of component type and composite clearance criterion, each residential unit either passed clearance, failed clearance, or yielded inconclusive results, according to whether the sets of simulated composite samples for the unit either all resulted in a pass decision, all resulted in a fail decision, or had same combination of pass and fail decisions, respectively.

Table D1-6. Numbers of Residential Units that Pass or Fail Clearance, Based on Individual Sample Clearance Results vs. Simulated Composite Clearance Results, Using Data from Grantees with Higher Floor Dust-lead Clearance Standard.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	1775	97	1854	72	1546	33
	Inconclusive	0	63	0	7	0	1
	Fail	0	157	0	98	0	117
Standard/n	Pass	1622	0	1797	0	1527	0
	Inconclusive	78	0	2	0	1	0
	Fail	75	317	55	177	18	151
2xStandard/n	Pass	1730	8	1829	8	1533	2
	Inconclusive	28	62	0	2	0	1
	Fail	17	247	25	167	13	148

Values of the four performance characteristics defined in Section 5.4.3 (sensitivity, specificity, positive predictive value, negative predictive value) are presented in Table D1-7 for each combination of component type and composite clearance criterion. By design, the sensitivity for the Standard/n Rule is always 1.00 (as all sets of simulated composite samples would fail if at least one individual sample result failed) while the specificity for this rule is estimated at 0.91 for floors, 0.97 for window sills, and 0.99 for window troughs. In contrast, the specificity of the Standard Rule is always 1.00 (as all sets of simulated composite samples would pass if all individual samples passed) while the sensitivity for this rule is estimated at 0.50 for floors, 0.55 for window sills, and 0.77 for window troughs. The 2×Standard/n Rule attempts to maximize both sensitivity and specificity. For the 2×Standard/n Rule, the values of sensitivity are higher than those calculated for the Standard Rule, while the values of specificity are higher than or equal to those calculated for the Standard/n Rule. Estimates of sensitivity and specificity in these examples are always conservative, because inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

Table D1-7. Performance Characteristics of Composite Clearance Criteria Based on Data from Grantees with Higher Floor Dust-lead Clearance Standard.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2xStandard/n
Floors	Sensitivity	0.50	1.00	0.78
	Specificity	1.00	0.91	0.97
	PPV	1.00	0.81	0.94
	NPV	0.95	1.00	1.00
Window Sills	Sensitivity	0.55	1.00	0.94
	Specificity	1.00	0.97	0.99
	PPV	1.00	0.76	0.87
	NPV	0.96	1.00	1.00
Window Troughs	Sensitivity	0.77	1.00	0.98
	Specificity	1.00	0.99	0.99
	PPV	1.00	0.89	0.92
	NPV	0.98	1.00	1.00

The above estimates of the performance characteristics illustrate that the three composite clearance testing criteria have different specificity and sensitivity rates. These rates correspond to the consistency between clearance decisions and the true lead hazards present in the various locations sampled (assuming the individual sample lead-loading results are representative of these lead hazards). To further characterize the performance of each of the three composite clearance criteria, the following logistic regression model was fitted to clearance data for each combination of component type and composite clearance criterion:

$$\mathrm{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \mathrm{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

For each component type, the estimated relationship between the probability of passing clearance and the maximum lead-loading is presented graphically in Figure D1-9. In this figure, the solid, long-dashed, and finely-dashed lines represent the estimated relationship for the Standard, Standard/n, and 2×Standard/n Rules, respectively.

For each combination of component type and composite clearance criterion, Table D1-8 provides parameter estimates and associated standard errors from fitting the above logistic regression model to data. Table D1-8 also presents estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2 and 4 times the associated HUD interim standard for individual samples. Results from these logistic regression model fits show that there is a better than 50% chance that a residential unit will pass clearance for floors and window sills under the Standard Rule for composite sampling, when there is an individual sample location which has a lead-loading level that is equal to twice the HUD clearance standard. Estimates for the Standard/n Rule demonstrate that this rule's high sensitivity (probability of passing is below 17% when the maximum individual sample lead loading is greater than or equal to the HUD Standard) along with a loss in specificity (probability of passing is 89% for floors and 94% for window sills when the maximum individual sample lead loading is equal to ½ HUD Standard). Once again, the 2×Standard/n Rule is shown to be a compromise between the Standard and Standard/n Rules. At ½ the HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is one or nearly one, while at 2×HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is zero or nearly zero.

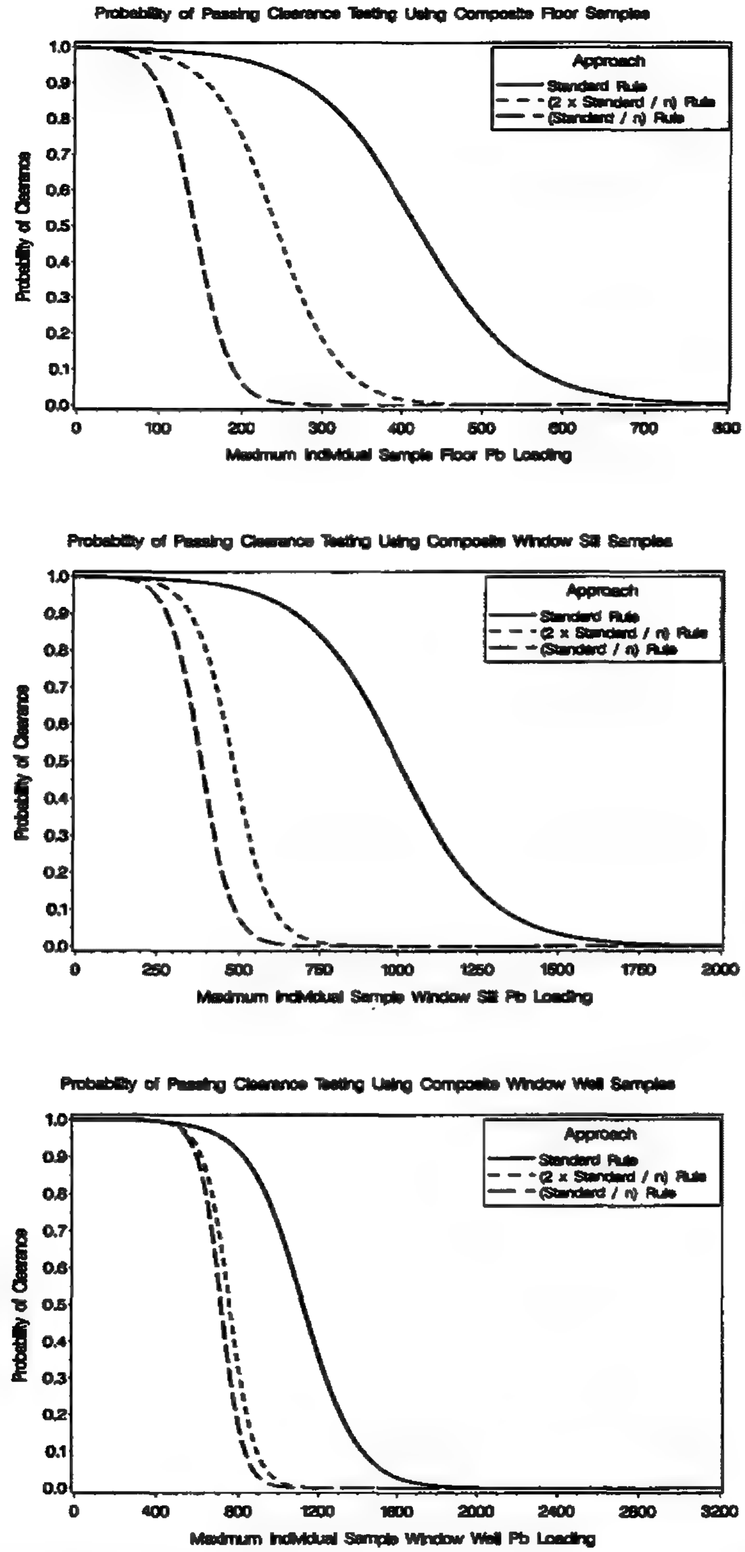

Figure D1-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Results by Component Type Based on Simulated Composite Samples from the Grantees with Higher Floor Dust-lead Clearance Standard in the HUD Grantee Program.

Table D1-8. Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, under Three Different Composite Sampling Decision Rules, Using Data from the Grantees with Higher Floor Dust-lead Clearance Standard in the HUD Grantee Program.

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance when the Maximum Individual Sample Result Within a House is Equal to			
		Pass	Inconclusive	Fail	β_0	s.e. (β_0)	β_1	s.e. (β_1)	1/2 HUD Standard	HUD Standard	2 * HUD Standard	4 * HUD Standard
Floors	Standard	1872	63	157	6.290	0.384	-0.015	0.001	0.99	0.96	0.57	0.00
	2xStandard/n	1738	90	264	6.251	0.349	-0.026	0.002	0.98	0.75	0.02	0.00
	Standard/n	1622	78	392	6.840	0.404	-0.048	0.003	0.89	0.06	0.00	0.00
Window Sills	Standard	1926	7	98	6.693	0.484	-0.007	0.001	0.99	0.97	0.50	0.00
	2xStandard/n	1837	2	192	8.134	0.696	-0.017	0.002	0.98	0.41	0.00	0.00
	Standard/n	1797	2	232	8.146	0.667	-0.021	0.002	0.94	0.07	0.00	0.00
Window Troughs	Standard	1579	1	117	8.320	0.882	-0.007	0.001	1.00	0.92	0.03	0.00
	2xStandard/n	1535	1	161	12.192	1.897	-0.016	0.003	1.00	0.33	0.00	0.00
	Standard/n	1527	1	169	13.313	2.180	-0.019	0.003	1.00	0.17	0.00	0.00

APPENDIX D2

Grantees with Lower Floor Dust-Lead Clearance Standard in the HUD Grantee Program

APPENDIX D2

GRANTEES WITH LOWER FLOOR DUST-LEAD CLEARANCE STANDARD IN THE HUD GRANTEE PROGRAM

Appendix D2 presents analysis results on the clearance data collected from five grantees that used a lower floor dust-lead clearance standard (i.e. 100 µg/ft^2 or 80 µg/ft^2). The clearance standards still remained at 500 µg/ft^2 and 800 µg/ft^2 for window sills and window troughs, respectively. The five grantees are Cleveland, Chicago, New Jersey, and New York City which used 100 µg/ft^2 as a floor dust-lead clearance standard, and Minnesota which used 80 µg/ft^2.

Note that, as explained in Appendix D, 13 dwelling units did not have first site visit dust-lead clearance data and were therefore not included in the first site visit analysis. However, since these dwelling units had data for other site visits, they were included in those analyses. Fifty (50) dwelling units did not have second site visit data but did have data for other site visits (including first site visit data) and were included in those analyses.

To be consistent with other data sources presented in this report, a floor dust-lead clearance sample in the analyses presented below was labeled as a "pass" if its loading was below 200 µg/ft^2 and as a "fail" if its lead loading was greater than or equal to 200 µg/ft^2, despite the lower clearance standard used by the grantee.

D2-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

Individual dust wipe samples were collected from floors, window sills and window troughs as part of the HUD Grantee Program. A total of 7,664 samples were taken from 4,936 rooms in 1,038 residential units from five grantees using the lower floor dust-lead clearance standard (either 100 or 80 µg/ft^2). Table D2-1 presents the number of individual samples, work areas and residential units that passed or failed clearance testing within each combination of component type and site visit. Approximately 93% (7,135/7,664) of the dust samples were collected during the first site visit to a residential unit. On the first site visit, 95% (6,782/7,135) of the dust samples fell below the clearance standards of 200 µg/ft^2 for floors, 500 µg/ft^2 for window sills and 800 µg/ft^2 for window troughs while 93% (4,191/4,522) of the rooms and 78%

(796/1,025) of the residential units passed clearance. The increase in the failure rate from the percentage of individual samples that fail to the percentage of rooms and residential units that fail is attributable to the fact that if any individual sample exceeded the standard and failed clearance, then both the room and residential unit also failed clearance.

Table D2-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit from the Grantees with Lower Floor Dust-lead Clearance Standard in the HUD Grantee Program

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	3486	156	3642	3410	154	3564	909	112	1021
	Sill	2068	79	2147	2044	79	2123	897	71	968
	Trough	1228	118	1346	1221	118	1339	772	101	873
	All	6782	353	7135	4191	331	4522	796	229	1025
Second	Floor	226	19	245	216	19	235	131	16	147
	Sill	83	8	91	82	8	90	66	8	74
	Trough	90	18	108	90	18	108	75	17	92
	All	399	45	444	350	44	394	189	39	228
Third	Floor	30	3	33	30	3	33	23	3	26
	Sill	18	0	18	18	0	18	15	0	15
	Trough	19	4	23	19	4	23	18	4	22
	All	67	7	74	64	7	71	45	7	52
Fourth	Floor	7	0	7	7	0	7	4	0	4
	Sill	0	0	0	0	0	0	0	0	0
	Trough	4	0	4	4	0	4	4	0	4
	All	11	0	11	11	0	11	8	0	8
Total	Floor	3749	178	3927	3650	156	3806	1005	25	1030
	Sill	2169	87	2256	2138	81	2219	951	22	973
	Trough	1341	140	1481	1333	124	1457	849	32	881
	All	7259	405	7664	4595	341	4936	971	67	1038

The failure rate for individual samples during the first site visit was at 4.3% (156/3,642) for floors, at 3.7% (79/2,147) for window sills, and at 8.8% (118/1,346) for window trough samples. The failure rate for individual samples showed an increase from the first site visit to the second site visit and again from the second visit to the third site visit.

Of the 1,025 dwelling units in Table D2-1 for which initial post-intervention clearance sampling (first site visit) data were available, 77.7% (796/1,025) passed on the first attempt. A total of 11.0% (112/1,021) had at least one floor location with a dust-lead loading above the clearance level. This failure rate was higher than that reported for window sills (7.3%, 71/968) and lower than that reported for window troughs (11.6%, 101/873).

D2-2. Objective 2: Characterization of the Distribution of the Dust-lead Loadings, Geometric Mean Dust-lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

Preliminary assessment of the data indicated that the distributions of dust-lead loading clearance sample results were highly skewed. Therefore, a natural logarithm transformation was applied to the data.

For the clearance data collected from five grantees with the lower floor dust-lead clearance standard, Table D2-2 lists the geometric mean dust-lead loading, variance components (within-home variability and between-home variability) associated with these loadings, and a 95% confidence interval for the geometric mean, calculated for each site visit and component type. No sill dust sample results were available for the fourth site visit. Notice from this table that all of the variance components are within a single order of magnitude of each other. Also, the lengths of the confidence intervals increase from the first site visit to the third site visit for any given component. The increase in the length of the confidence intervals is due primarily to the decrease in the number of samples used to estimate the variance components.

The geometric mean lead loadings and their 95% confidence intervals were used to compare trends between site visits for a given component type and to compare average results between component types within a site visit. If the 95% confidence intervals on two geometric means do not overlap, then these two geometric means are statistically significantly different at a level less than 0.05. A comparison across site visits shows that the geometric means, from the first site visit to the third site visit, increase gradually but were not statistically significant:

Table D2-2. Geometric Mean and Variance Component Estimates for Grantees with Lower Floor Dust-lead Clearance Standard in the HUD Grantee Program

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	3642	3564	1021	12.3	1.44	1.13	11.16	13.55
	Sill	2147	2123	968	24.9	1.49	1.55	22.19	27.99
	Trough	1346	1339	873	66.5	1.59	1.39	58.28	75.87
Second	Floor	245	235	147	13.8	1.45	1.26	10.30	18.56
	Sill	91	90	74	30.5	2.33	1.05	16.96	54.75
	Trough	108	108	92	99.0	1.28	1.85	63.30	154.96
Third	Floor	33	33	26	19.7	1.52	1.39	8.84	43.88
	Sill	18	18	15	38.6	2.22	0.51	10.99	135.39
	Trough	23	23	22	97.1	2.06	1.90	28.20	334.13
Fourth	Floor	7	7	4	11.3	1.16	0.58	1.49	85.22
	Trough	4	4	4	130.1	0.11	0.00	109.4	154.74

12.3 μg/ft², 13.8 μg/ft², 19.7 μg/ft² for floors and 24.9 μg/ft², 30.5 μg/ft², 38.6 μg/ft² for window sills. The geometric means for window troughs increase from 66.5 μg/ft² to 99.0 μg/ft² from the first site visit to the second site visit but decrease to 97.1 μg/ft² on the third site visit. A comparison of the components tested for the first site visit shows that the floor dust-lead loadings were significantly less than the window sill dust-lead loadings, which were in turn significantly less than the window trough dust-lead loadings. Note that estimates from the fourth site visit were associated with very small sample sizes and may not be reliable for establishing trends.

Figures D2-1 and D2-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures D2-3 to D2-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures D2-6 to D2-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

D2-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships in dust-lead loadings among floor, window sill, and window trough wipe samples collected from within the same room are another important aspect of examining a clearance testing program. By estimating linear correlation coefficients, the strength of these relationships can be assessed. Table D2-3 displays the Pearson product-moment correlation coefficients and associated sample sizes for the log-transformed dust-lead loading measurements of individual floor, window sill, and window trough samples taken within the same room. For the first site visit, dust-lead loadings for floor samples were significantly positively correlated at the 0.01 level with loadings for both window sill and window trough samples, as was the correlation between window sills and window troughs. The correlations from the second site visit were again significantly positive for the relationships between floor and sill dust-lead loadings (at the 0.01 level) and between floor and trough dust-lead loadings (at the 0.05 level). Data was not sufficient to estimate the correlation between window sill and window trough dust-lead loadings from the second site visit.

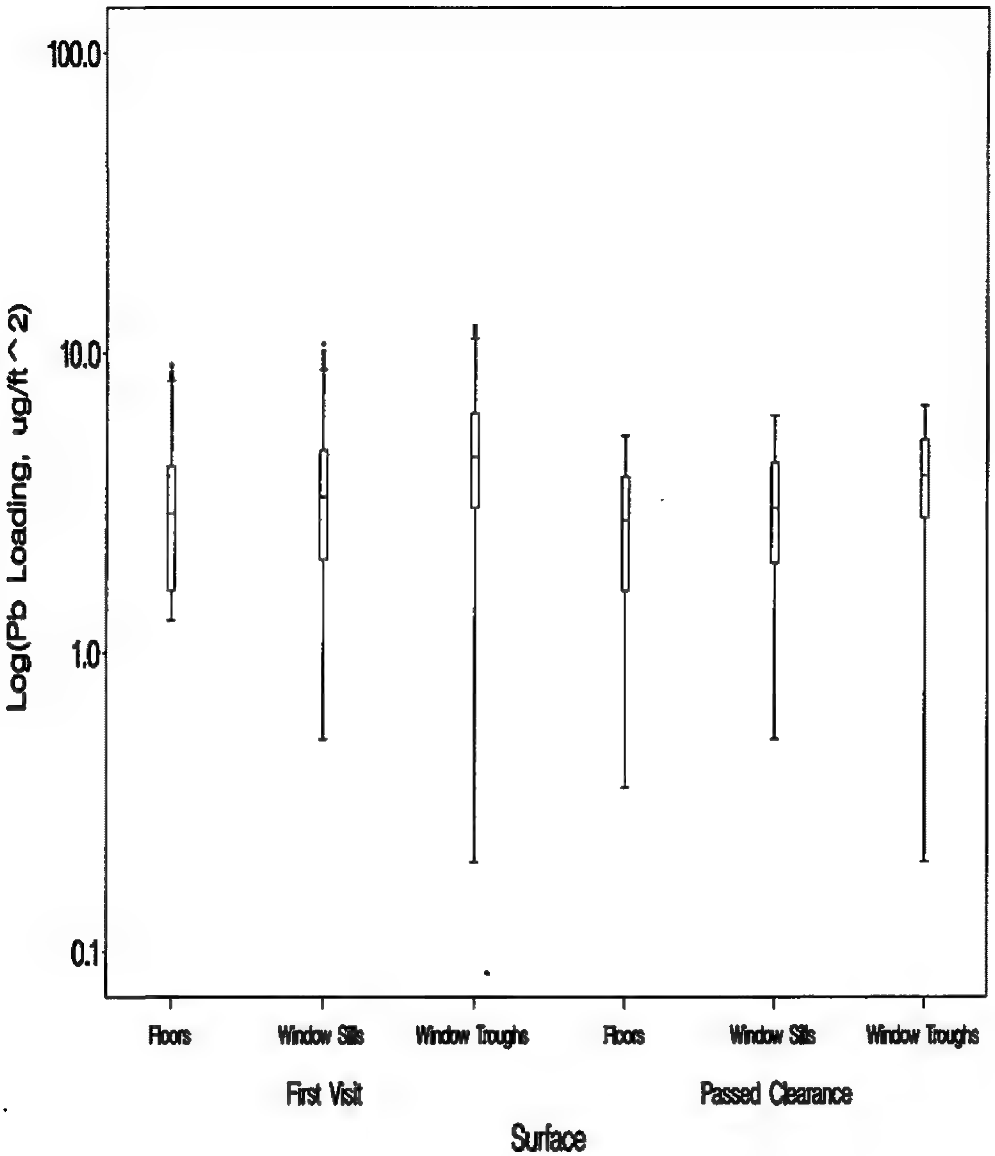

Figure D2-1. Comparison of ln-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.

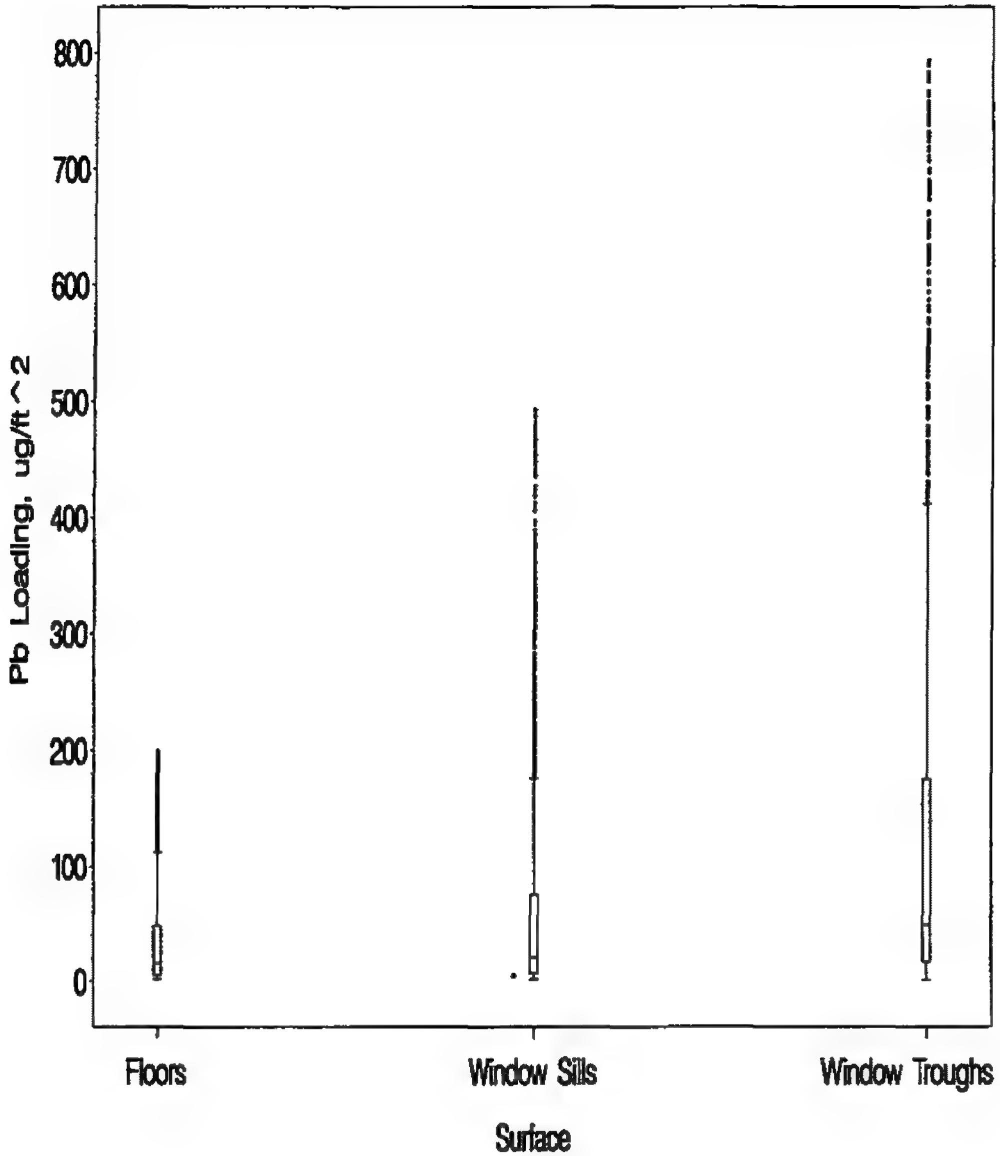

Figure D2-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

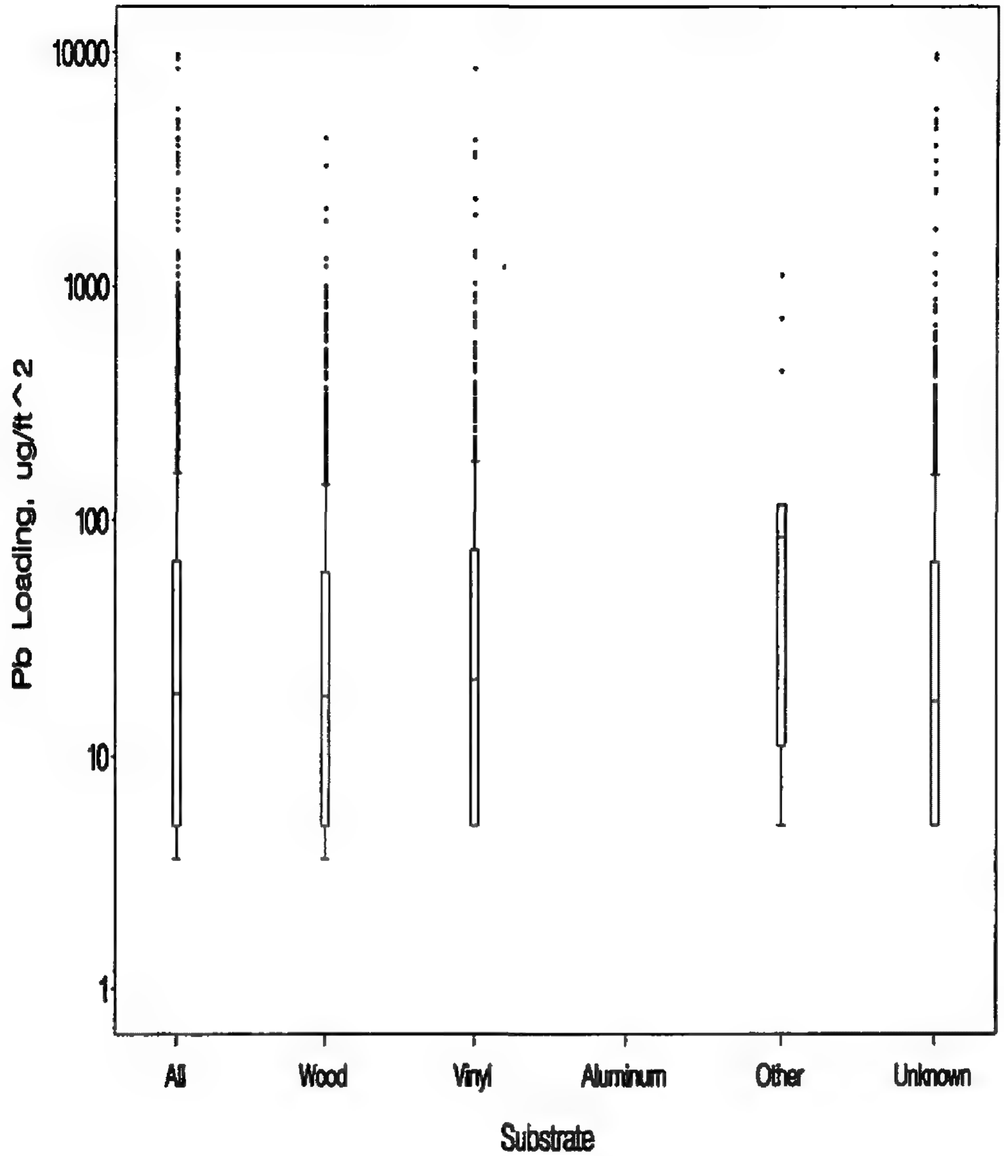

Figure D2-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

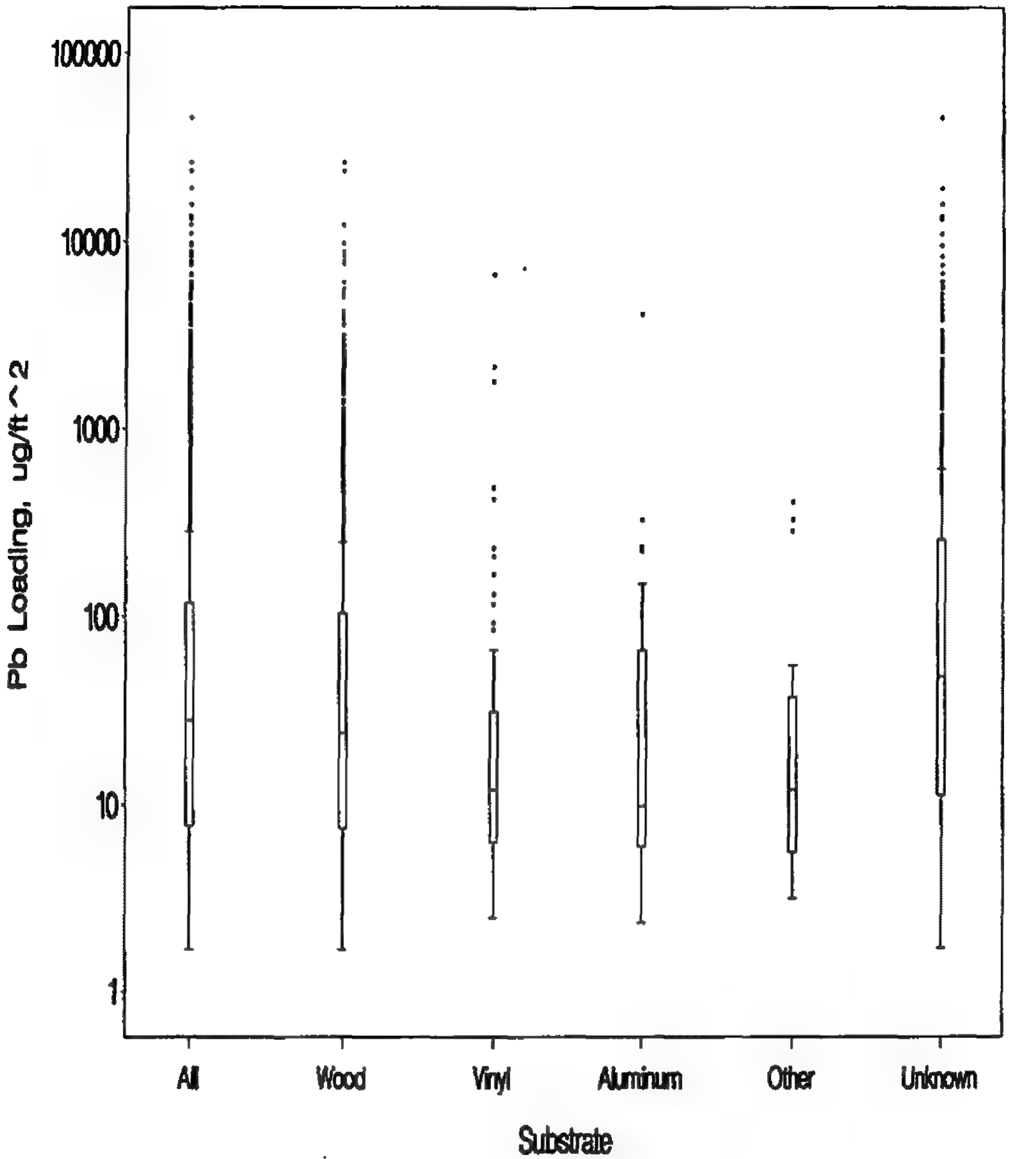

Figure D2-4. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.

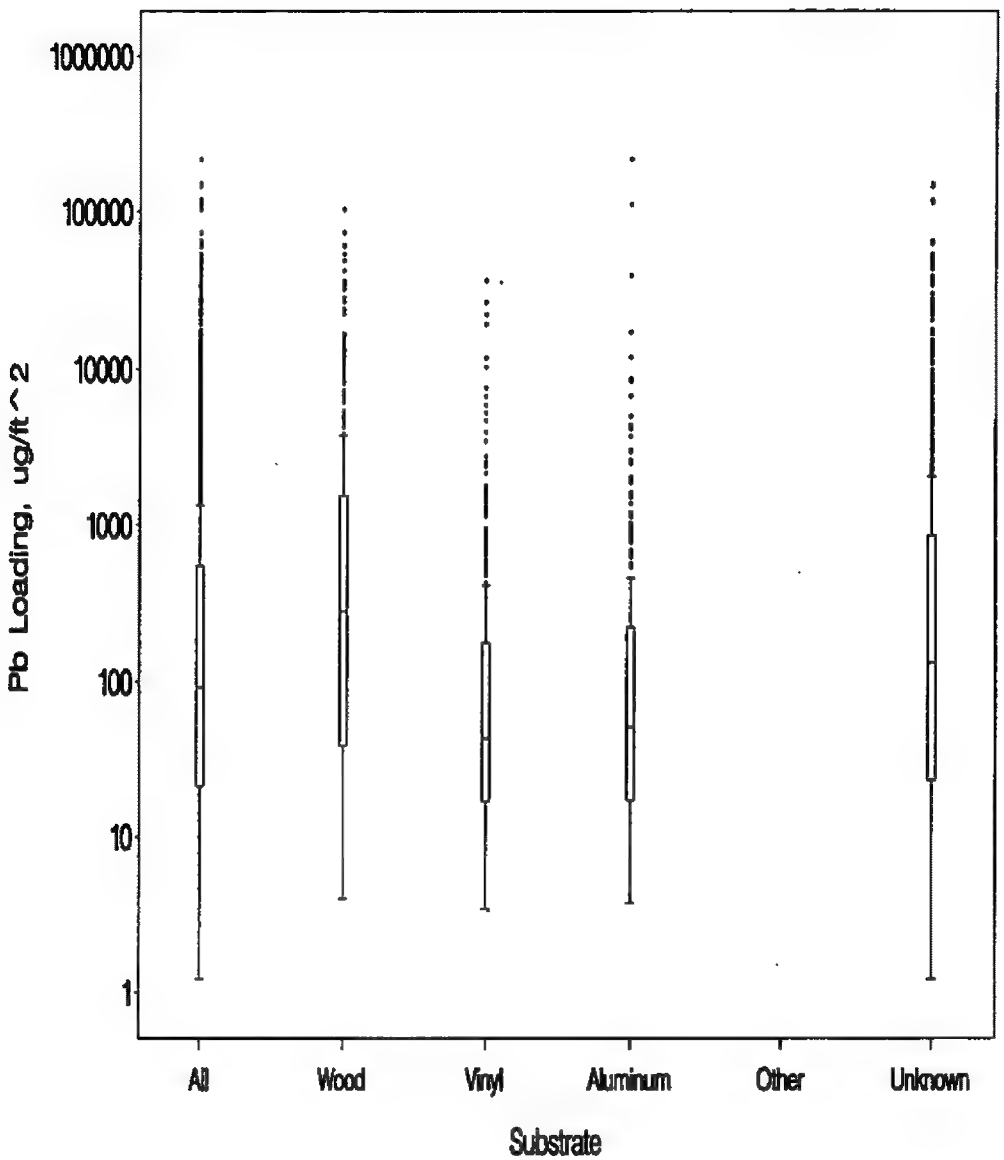

Figure D2-5. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.

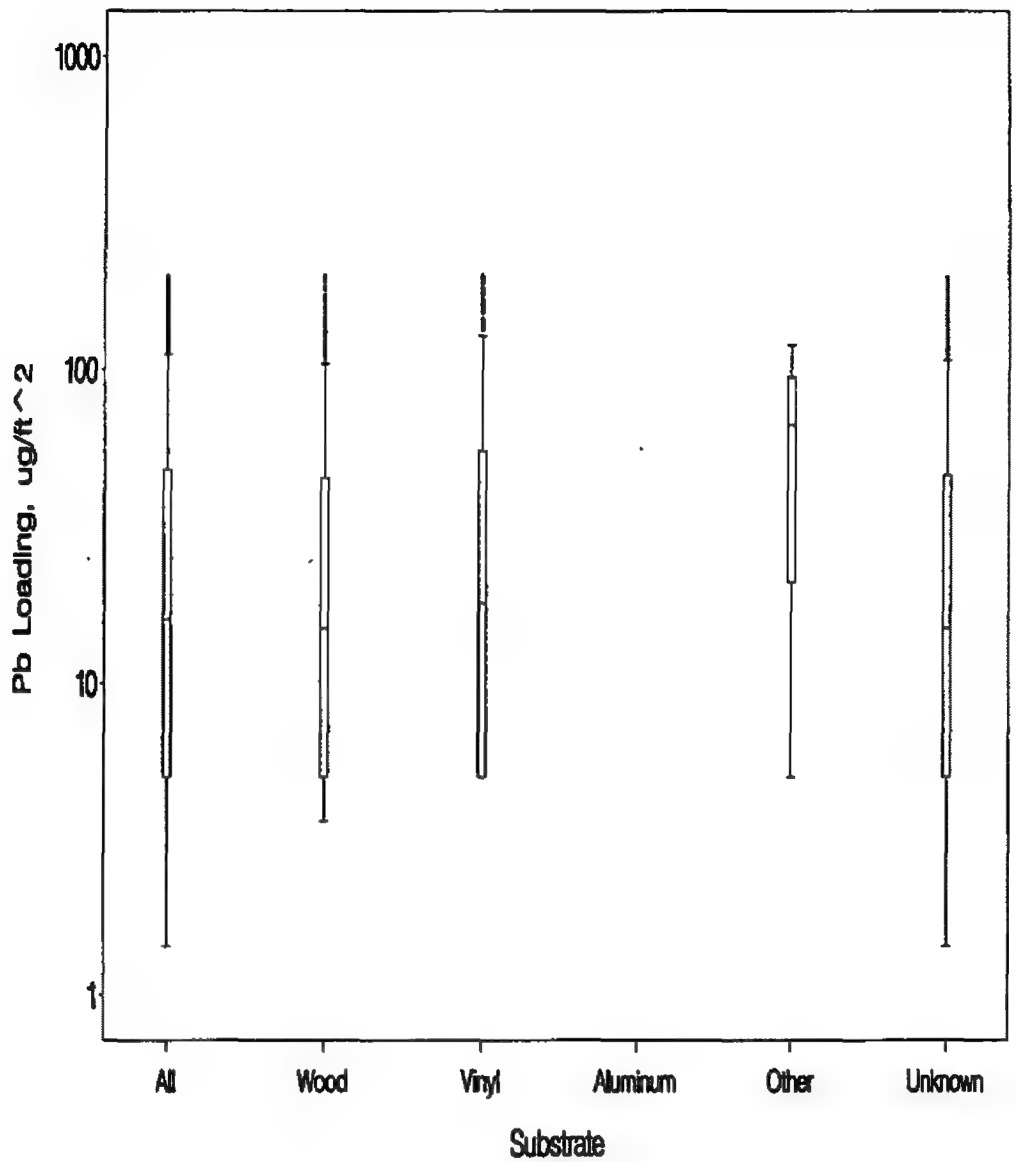

Figure D2-6. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

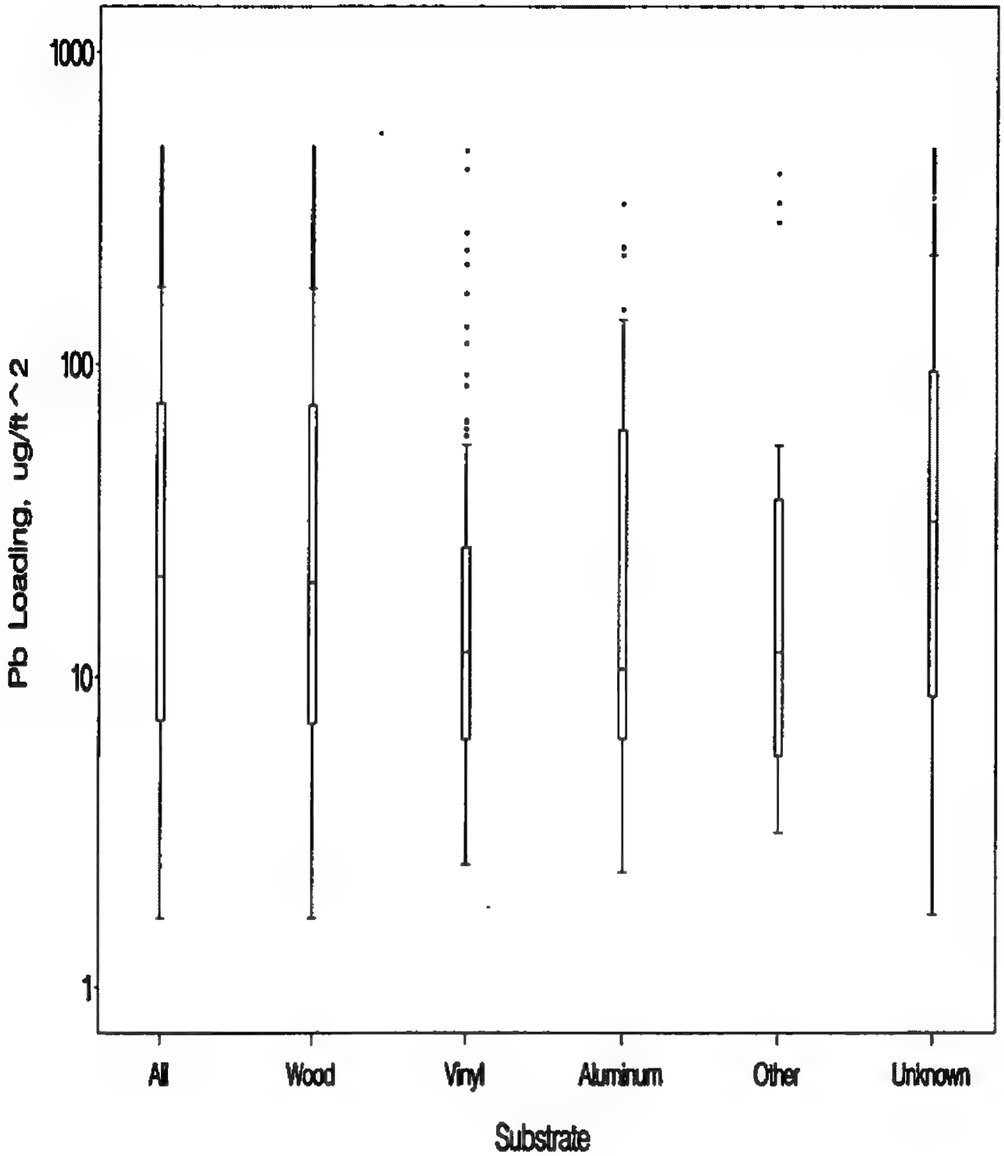

Figure D2-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

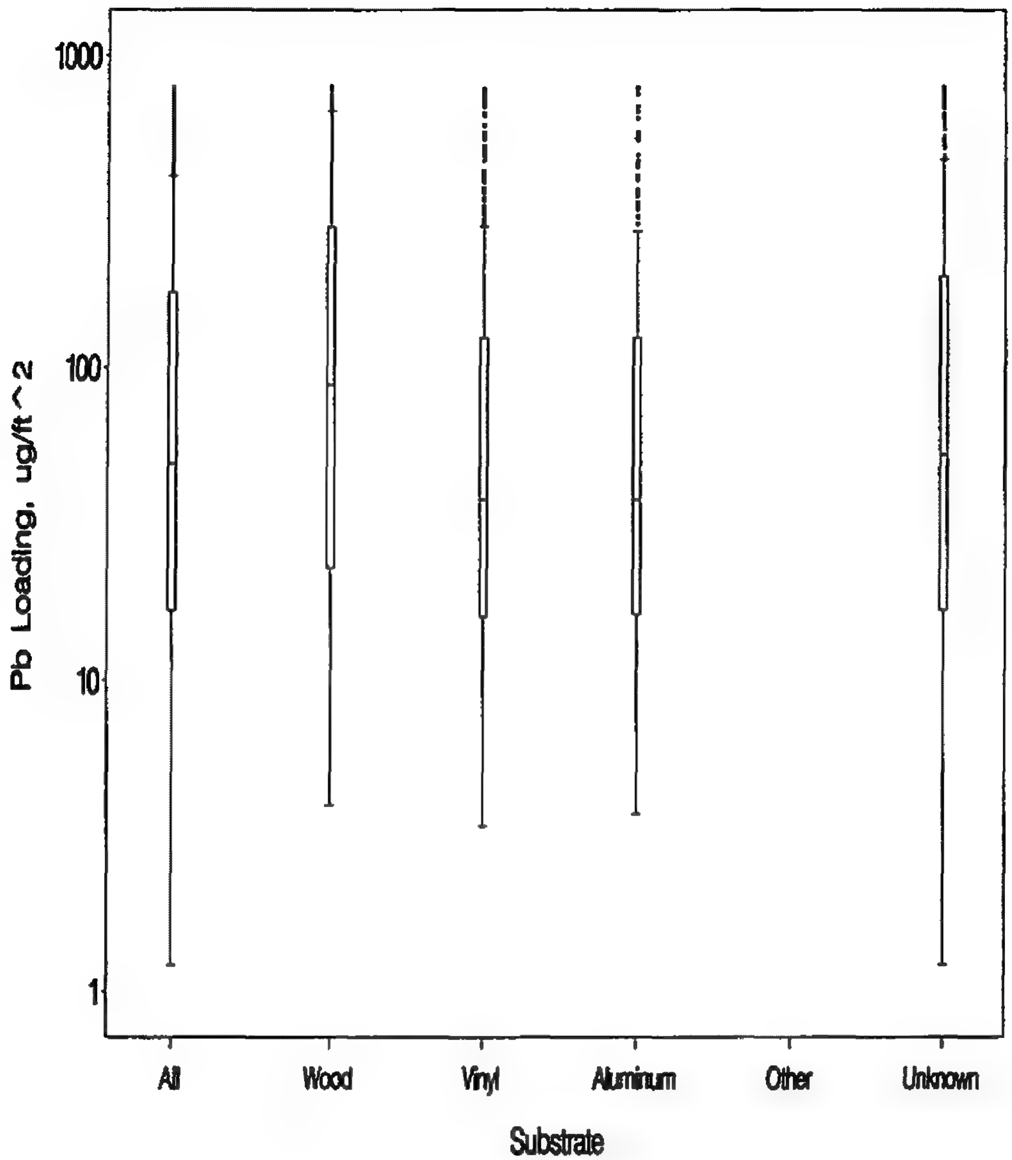

Figure D2-8. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

Table D2-3. Observed Within-Room Correlation Coefficients Between Dust-Lead Loading Measurements Collected From Floors, Window Sills and Window Troughs from the Grantees with Lower Floor Dust-lead Clearance Standard in the HUD Grantee Program.

Site Visit	Observed Within Room Correlation Coefficients Between					
	Floors and Sills		Floors and Troughs		Sills and Troughs	
	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n	$\rho_{Sills\ Troughs}$	n
First	0.48[a]	1687	0.40[a]	809	0.59[a]	20
Second	0.20[a]	21	0.53[b]	16	.	.

[a] Statistically significantly different from zero at the 0.01 level.
[b] Statistically significantly different from zero at the 0.05 level.

The conditional probabilities of a sample passing or failing a standard are given in Table D2-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Table D2-4, results from contingency table estimates and normal theory estimates are roughly consistent. For both types of estimates and both data sets included in the analysis, the probability that one component passes clearance given that another component passes clearance ranges from 80% to 97%. The probability that a floor sample is less than 200 $\mu g/ft^2$, given the samples from the window sills are less than 500 $\mu g/ft^2$, is the highest at 97.4%.

For both types of estimates and both data sets included in the analysis, the probability that one component fails clearance testing given that another component in the same room fails clearance testing ranged from 13% to 67%.

D2-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

Table D2-5 provides, for each component type, the number of residential units having a given number of samples collected from a given component type. Across component types, most of the residential units had fewer than four clearance samples collected. Data for residential units having more than four samples from a given component type were used to construct multiple

Table D2-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
$P(F<200 \mid S<500)$	0.974	0.900	0.961	0.919	$P(F\geq 200 \mid S\geq 500)$	0.132	0.500	0.214	0.288
$P(S<500 \mid F<200)$	0.971	0.900	0.935	0.885	$P(S\geq 500 \mid F\geq 200)$	0.142	0.500	0.320	0.375
$P(F<200 \mid T<800)$	0.960	0.900	0.953	0.939	$P(F\geq 200 \mid T\geq 800)$	0.137	0.500	0.173	0.2657
$P(T<800 \mid F<200)$	0.918	0.900	0.891	0.799	$P(T\geq 800 \mid F\geq 200)$	0.256	0.500	0.343	0.586
$P(S<500 \mid T<800)$	0.941	0.900	0.926	0.922	$P(S\geq 500 \mid T\geq 800)$	0.666	0.500	0.366	0.350
$P(T<800 \mid S<500)$	0.941	0.900	0.852	0.815	$P(T\geq 800 \mid S\geq 500)$	0.666	0.500	0.556	0.592
$P(F<200 \mid S<500, T<800)$	.	1.000	.	0.948	$P(F\geq 200 \mid S\geq 500, T\geq 800)$	.	0.000	.	0.372
$P(S<500 \mid F<200, T<800)$	.	1.000	.	0.931	$P(S\geq 500 \mid F\geq 200, T\geq 800)$	.	0.000	.	0.490
$P(T<800 \mid F<200, S<500)$	.	1.000	.	0.840	$P(T\geq 800 \mid F\geq 200, S\geq 500)$	.	0.000	.	0.766

Table D2-5. **Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data from the Grantees with Lower Floor Dust-lead Clearance Standard in the HUD Grantee Program.**

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	129	120	495
2	124	587	302
3	159	214	60
4	346	40	13
5	201	4	3
6	50	2	0
7	7	0	0
8	2	0	0
9 +	3	1	0
Total	1021	968	873
Total with N ≥5	263	7	3

simulated composite samples. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples. From Table D2-5, the number of homes with five or more samples was 263 for floors, 7 homes for window sills, and 3 homes for window troughs. Therefore, data for approximately 26% (263/1,021), 1% (7/968), and less than 1% (3/873) of the residential units were used when constructing multiple simulated composite samples from floors, window sills, and window troughs, respectively.

For each component type within a residential unit, the set of individual clearance sample lead loading results for the first site visit were used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria introduced in Section 5.4.2 (Standard, Standard/n, and 2×Standard/n). The construction of simulated composite samples is discussed in Section 5.4.1. For each combination of component type and composite clearance criterion, each residential unit either passed clearance, failed clearance, or yielded inconclusive results, according to whether the sets of simulated composite samples for the unit

either all resulted in a pass decision, all resulted in a fail decision, or had some combination of pass and fail decisions, respectively.

Table D2-6. Numbers of Residential Units that Pass or Fail Clearance, Based on Individual Sample Clearance Results vs. Simulated Composite Clearance Results, Using Data from Grantees with Lower Floor Dust-lead Clearance Standard.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	909	39	897	34	772	20
	Inconclusive	0	18	0	2	0	0
	Fail	0	55	0	34	0	81
Standard/n	Pass	858	0	883	0	757	0
	Inconclusive	14	0	0	0	1	0
	Fail	37	112	14	70	14	101
2xStandard/n	Pass	896	7	892	4	762	0
	Inconclusive	4	13	0	1	0	0
	Fail	9	92	5	65	10	101

Values of the four performance characteristics defined in Section 5.4.3 (sensitivity, specificity, positive predictive value, negative predictive value) are presented in Table D2-7 for each combination of component type and composite clearance criterion. By design, the sensitivity for the Standard/n Rule is always 1.00 (as all sets of simulated composite samples would fail if at least one individual sample result failed) while the specificity for this rule is estimated at 0.94 for floors and 0.98 for both window sills and window troughs. In contrast, the specificity of the Standard Rule is always 1.00 (as all sets of simulated composite samples would pass if all individual samples passed) while the sensitivity for this rule is estimated at 0.49 for both floors and window sills and 0.80 for window troughs. The 2×Standard/n Rule attempts to maximize both sensitivity and specificity. For the 2×Standard/n Rule, the values of sensitivity are higher than those calculated for the Standard Rule, while the values of specificity are higher than those calculated for the Standard/n Rule. Estimates of sensitivity and specificity in these

examples are always conservative, because inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

Table D2-7. Performance Characteristics of Composite Clearance Criteria Based on Data from Grantees with Lower Floor Dust-lead Clearance Standard.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2xStandard/n
Floors	Sensitivity	0.49	1.00	0.82
	Specificity	1.00	0.94	0.99
	PPV	1.00	0.75	0.91
	NPV	0.96	1.00	0.99
Window Sills	Sensitivity	0.49	1.00	0.93
	Specificity	1.00	0.98	0.99
	PPV	1.00	0.83	0.93
	NPV	0.96	1.00	1.00
Window Troughs	Sensitivity	0.80	1.00	1.00
	Specificity	1.00	0.98	0.99
	PPV	1.00	0.88	0.91
	NPV	0.97	1.00	1.00

The above performance characteristics estimates illustrate that the three composite clearance testing criteria have different specificity and sensitivity rates. These rates correspond to the consistency between clearance decisions and the true lead hazards present in the various locations sampled (assuming the individual sample lead-loading results are representative of these lead hazards). To further characterize the performance of each of the three composite clearance criteria, the following logistic regression model was fitted to clearance data for each combination of component type and composite clearance criterion:

$$\mathrm{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \mathrm{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

For each component type, the estimated relationship between the probability of passing clearance and the maximum lead-loading is presented graphically in Figure D2-9. In this figure, the solid, long-dashed, and finely-dashed lines represent the estimated relationship for the Standard, Standard/n, and 2×Standard/n Rules, respectively.

For each combination of component type and composite clearance criterion, Table D2-8 provides parameter estimates and associated standard errors from fitting the above logistic regression model to data. Table D2-8 also presents estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2 and 4 times the associated HUD interim standard for individual samples. Results from these logistic regression model fits show that there is a better than 55% chance that a residential unit will pass clearance for floors and window sills under the Standard Rule for composite sampling, when there is an individual sample location which has a lead-loading level that is equal to twice the HUD clearance standard. Estimates for the Standard/n Rule demonstrate that this rule's high sensitivity (probability of passing is below 19% when the maximum individual sample lead loading is greater than or equal to the HUD Standard) along with a loss in specificity (probability of passing is 85% for floors, 96% for window sills, and 99% for window trough when the maximum individual sample lead loading is equal to ½ HUD Standard). Once again, the 2×Standard/n Rule is shown to be a compromise between the Standard and Standard/n Rules. At ½ the HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is one or nearly one, while at 2×HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is 0.00.

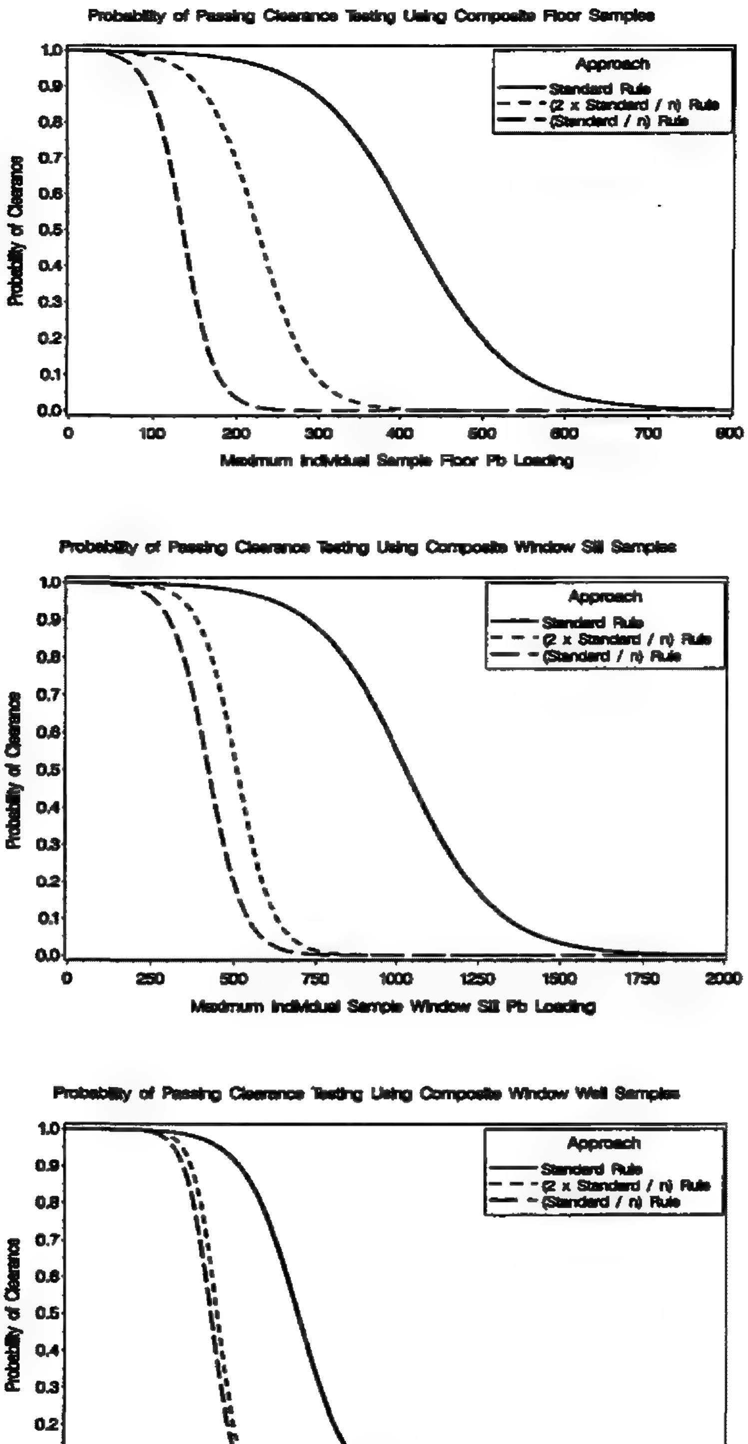

Figure D2-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Results by Component Type Based on Simulated Composite Samples from the Grantees with Lower Floor Dust-lead Clearance Standard in the HUD Grantee Program.

Table D2-8. **Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, under Three Different Composite Sampling Decision Rules, Using Data from the Grantees with Lower Floor Dust-lead Clearance Standard in the HUD Grantee Program.**

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance when the Maximum Individual Sample Result Within a House is Equal to			
		Pass	Incon-clusive	Fail	β_0	s.e. (β_0)	β_1	s.e. (β_1)	1/2 HUD Standard	HUD Standard	2 x HUD Standard	4 x HUD Standard
Floors	Standard	948	18	55	6.793	0.688	-0.016	0.002	0.99	0.97	0.56	0.00
	2xStandard/n	903	17	101	6.988	0.669	-0.031	0.003	0.98	0.68	0.00	0.00
	Standard/n	858	14	149	6.924	0.600	-0.052	0.005	0.85	0.03	0.00	0.00
Window Sills	Standard	931	2	34	7.354	0.917	-0.007	0.001	1.00	0.98	0.55	0.00
	2xStandard/n	896	1	70	9.111	1.316	-0.018	0.003	0.99	0.53	0.00	0.00
	Standard/n	883	0	84	7.754	0.844	-0.018	0.002	0.96	0.19	0.00	0.00
Window Troughs	Standard	792	0	81	8.537	1.187	-0.008	0.001	1.00	0.92	0.02	0.00
	2xStandard/n	762	0	111	12.559	2.302	-0.017	0.003	1.00	0.20	0.00	0.00
	Standard/n	757	1	115	11.400	1.918	-0.017	0.003	0.99	0.14	0.00	0.00

APPENDIX E

Atlantic City
Housing Authority

APPENDIX E

ATLANTIC CITY HOUSING AUTHORITY

The Atlantic City Housing Authority provided data from a comprehensive rehabilitation project performed on public housing buildings containing 10 to 23 multi-family housing units [18]. These two- to three-story brick buildings had lead-based paint on the doors, windows, radiators, trim, and stairwells. The doors and windows, along with most of the trim, were removed and replaced during abatement. Walls were enclosed by drywall, then painted, and steel panels were placed on the walls in the stairwells. Atlantic City Housing Authority employed a two-phased lead clearance process: worker entry clearance and re-occupancy clearance. The first set of lead clearance samples was collected after protected workers had finished the abatement job (worker lead clearance testing). The second set of lead clearance samples was taken after the renovation job was completed, but before the unit was occupied (re-occupancy clearance). Worker lead clearance testing results were used to ensure that the housing unit was safe for renovation workers (e.g. carpenters) to enter to complete their work. Re-occupancy clearance testing results were collected after all work on the housing unit was completed (including abatement and renovation and remodeling) to ensure that the unit was not contaminated by leaded dust and could be re-occupied by residents. This report only analyzed data collected in the re-occupancy clearance testing phase from the Atlantic City Housing Authority project. Wipe samples were collected in accordance with HUD protocol. Within each completed unit, one dust sample was collected from each room or area where abatement occurred. Sample locations were randomly distributed between floors and window troughs. Since the abatement process included removal of many windows, few window sill samples were tested. The standard interim HUD-established thresholds of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs were utilized in determining whether dust wipe samples passed or failed. In all cases where results exceeded the clearance thresholds, the areas were re-cleaned and re-tested until acceptable results were obtained.

E-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

Individual dust wipe samples were collected in Atlantic City from June 1994 through May 1995 as part of their clearance testing program. In all, 923 individual dust wipe samples were collected from floors, window sills, and window troughs within 779 rooms in 160 residential units. Table E-1 presents the number of individual samples, work areas, and

Table E-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit for Atlantic City.

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	516	38	554	479	37	516	127	32	159
	Sill	46	5	51	46	5	51	16	4	20
	Trough	252	6	258	248	6	254	114	5	119
	All	814	49	863	714	48	762	121	39	160
Second	Floor	29	13	42	25	12	37	12	4	16
	Trough	14	3	17	14	3	17	8	3	11
	All	43	16	59	31	15	46	13	7	20
Third	Trough	1	0	1	1	0	1	1	0	1
	All	1	0	1	1	0	1	1	0	1
Total	Floor	545	51	596	502	37	539	136	23	159
	Sill	46	5	51	46	5	51	16	4	20
	Trough	267	9	276	260	6	266	118	4	122
	All	858	65	923	733	46	779	133	27	160

residential units that passed or failed clearance testing within each combination of component type and site visit. Approximately 93% (863/923) of the dust samples were collected during the first site visit to a residential unit. While 94% (814/863) of the dust samples fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs, and 94% (714/762) of the rooms met clearance standards, only 76% (121/160) of the residential units passed clearance on the first site visit. This increase in the failure rate from the percentage of individual samples and rooms that fail to the percentage of residential units that fail is attributable to the fact that all individual samples must pass for a unit to pass.

That is, if any individual sample exceeds the standard and fails clearance, then the entire residential unit also fails clearance. Of the 39 residential units that failed clearance on the first site visit, 20 (51%) of these residential units are known to have been revisited for a second clearance testing site visit. Eventually, 133 of the 160 residential units (83%) are known to have passed clearance testing.

Floor samples accounted for 64% (554/863) of the first site visit samples while window troughs made up 30% (258/863) of the samples and window sills comprised the final 6% (51/863) of the first site visit samples. The failure rate for individual samples during the first site visit was highest for window sill samples (10% (5/51)) followed by floors (7% (38/554)) and window troughs (2% (6/258)).

E-2. Objective 2: Characterization of the Distribution of the Dust-Lead Loadings, Geometric Mean Dust-Lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

As seen in Table E-2, the geometric means for floor and window trough samples were 18.5 $\mu g/ft^2$ and 19.4 $\mu g/ft^2$, respectively. The within-house variance components and the between-house variance components are similar to those estimated for the other data sources.

Figures E-1 and E-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures E-3 to E-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures E-6 to E-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

E-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships among floor, window sill, and window trough wipe samples are another important aspect of examining a clearance testing program. One method to assess the relationships among individual floor, window sill, and window trough wipe samples collected from the same room is to estimate linear correlation coefficients. Table E-3 displays the Pearson product-moment correlation coefficients and the associated sample size for the log lead loading

Table E-2. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for the Atlantic City Data Set.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	554	516	159	18.5	0.84	1.00	15.8	21.7
	Sill	51	51	20	43.1	0.88	1.29	24.4	76.4
	Trough	258	254	119	19.4	0.93	1.19	15.5	24.3
Second	Floor	42	37	16	42.0	1.17	0.96	19.8	89.3
	Trough	17	17	11	58.6	2.02	1.38	12	287
Third	Trough	1	1	1	1.0	.	.	.	.

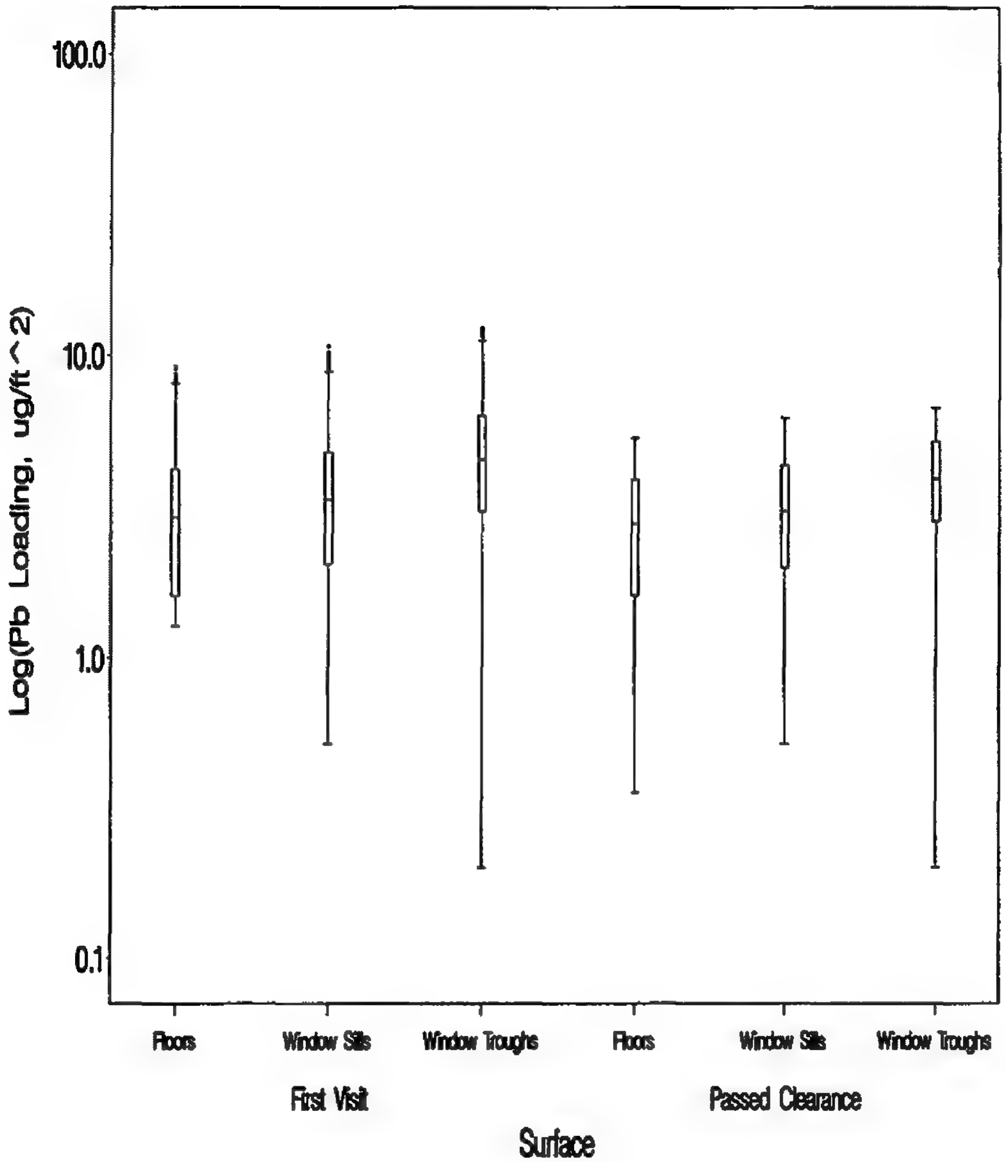

Figure E-1. Comparison of In-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.

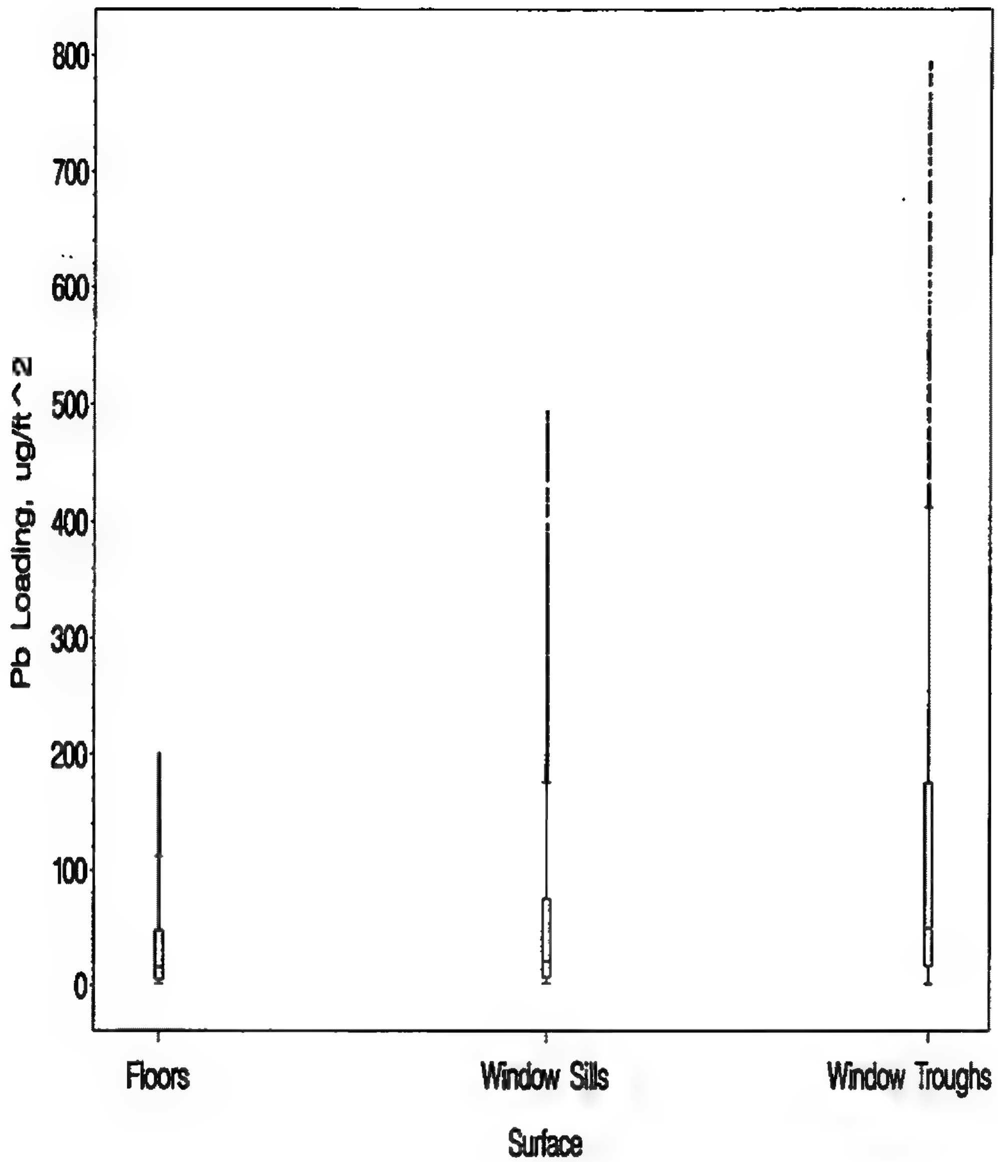

Figure E-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

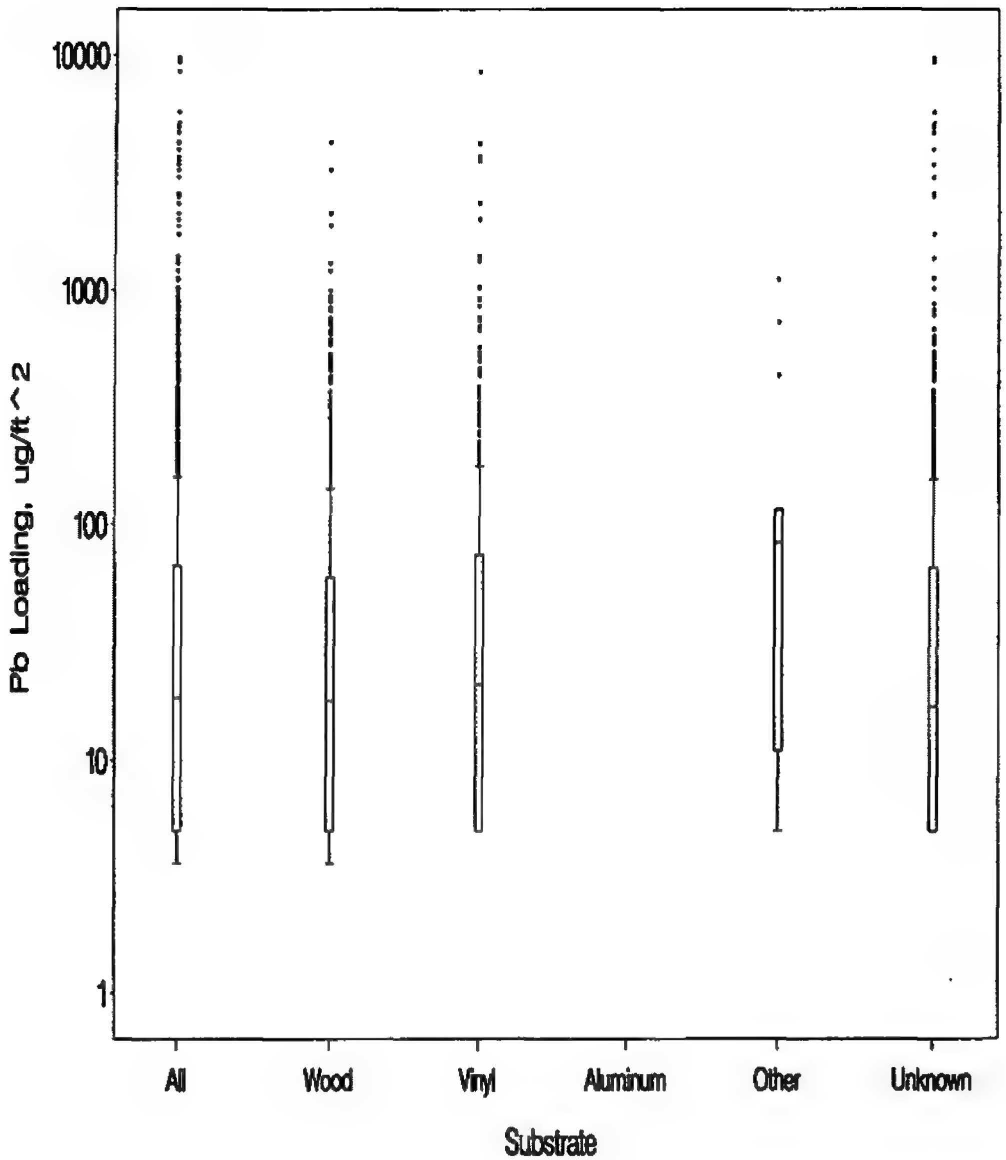

Figure E-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

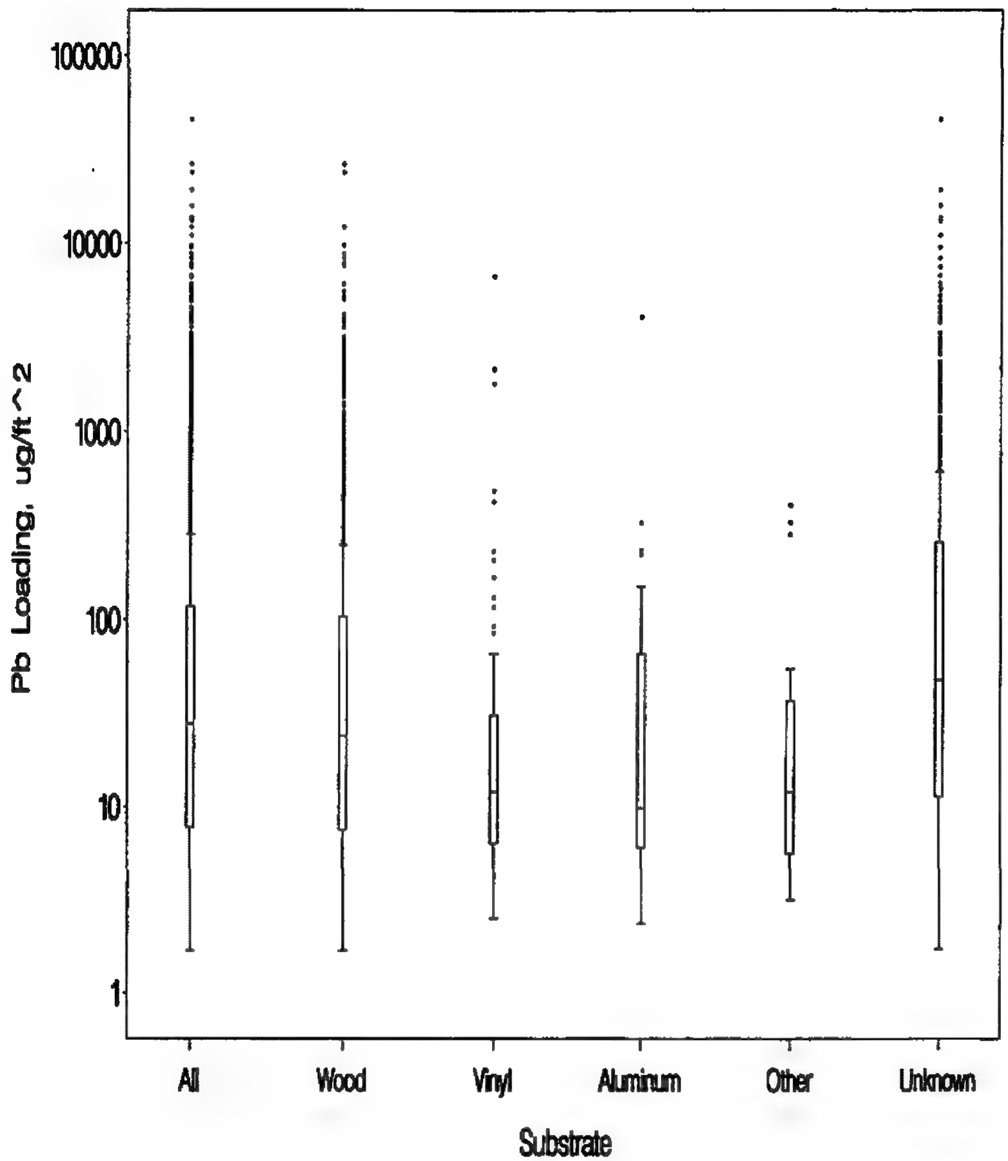

Figure E-4. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.

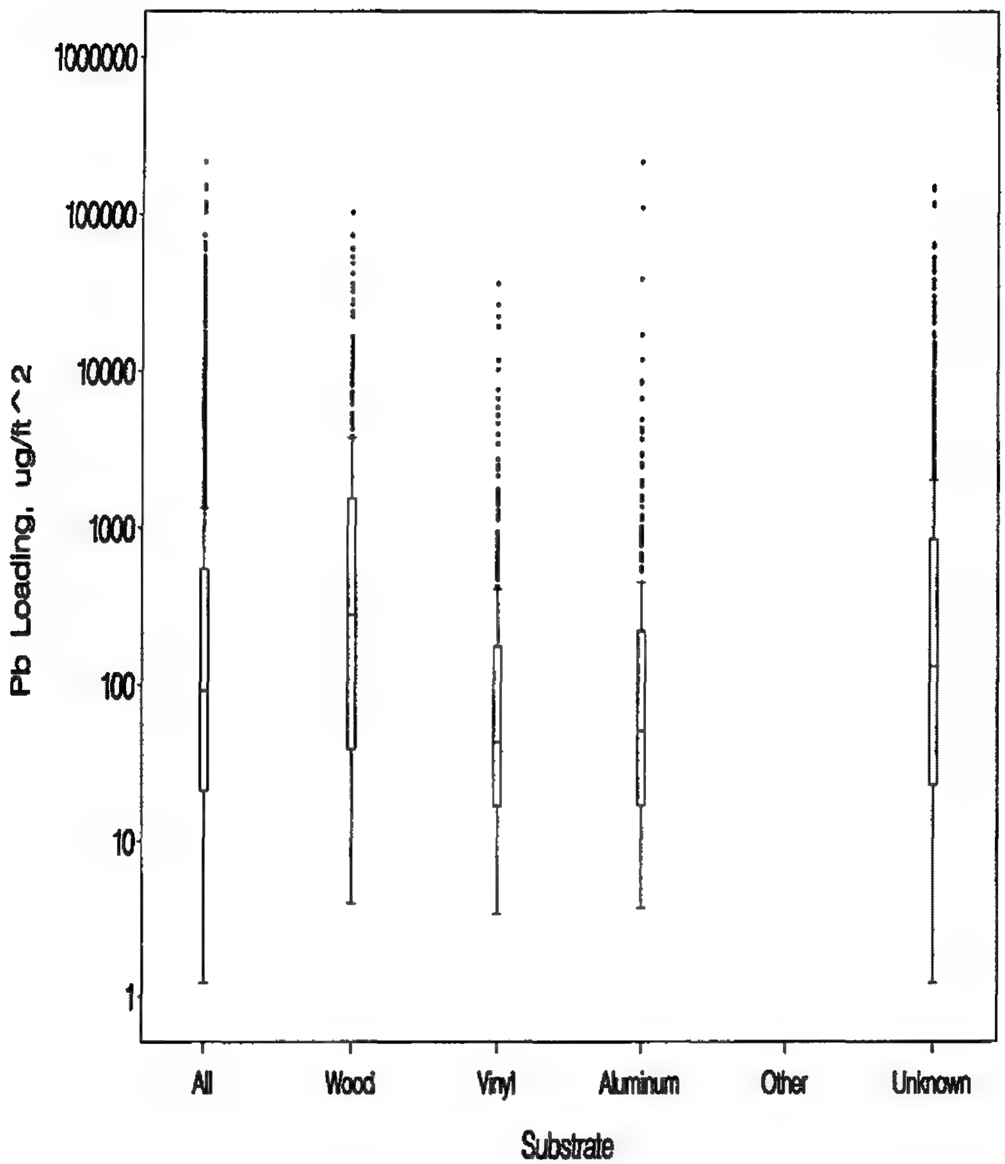

Figure E-5. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.

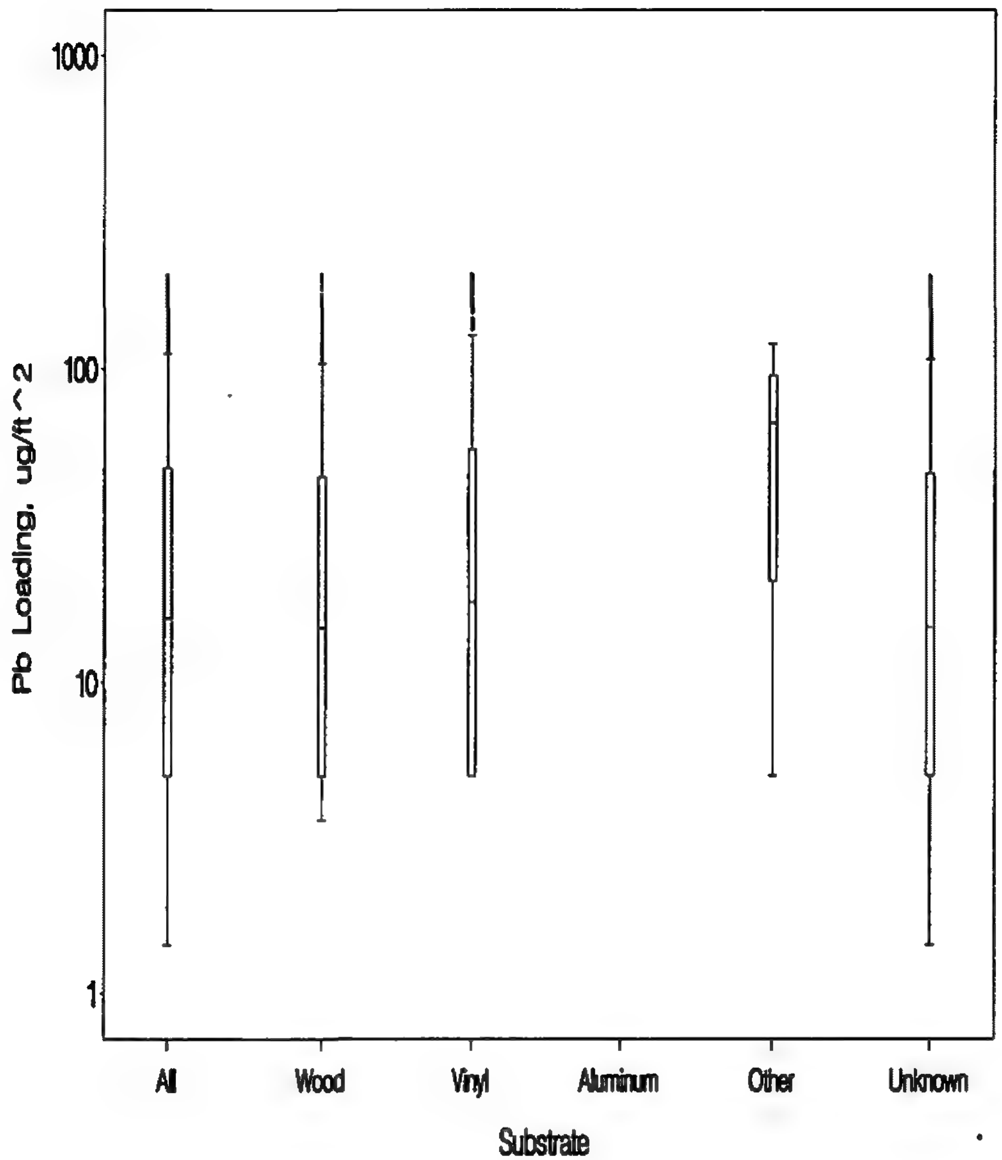

Figure E-6. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

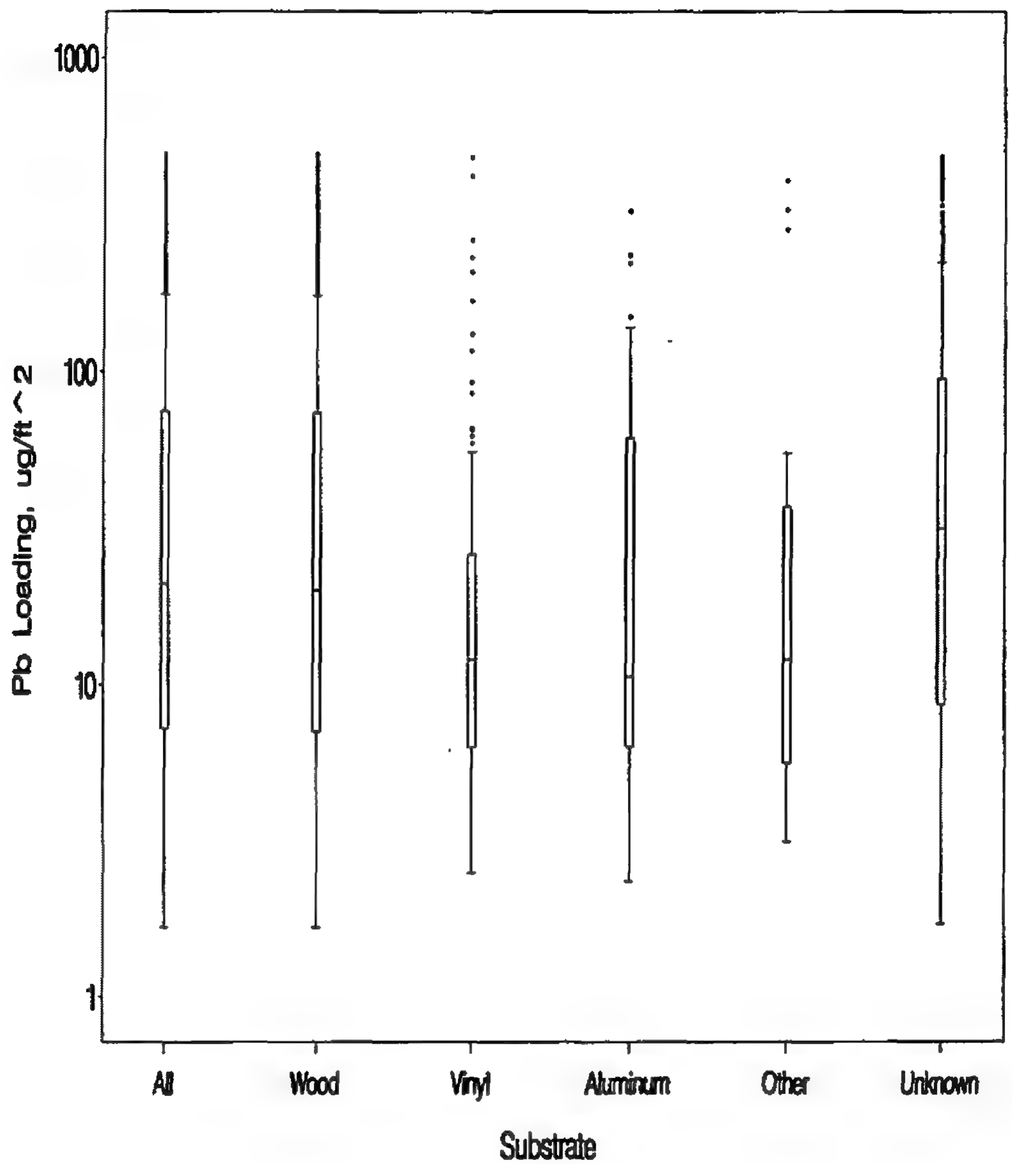

Figure E-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

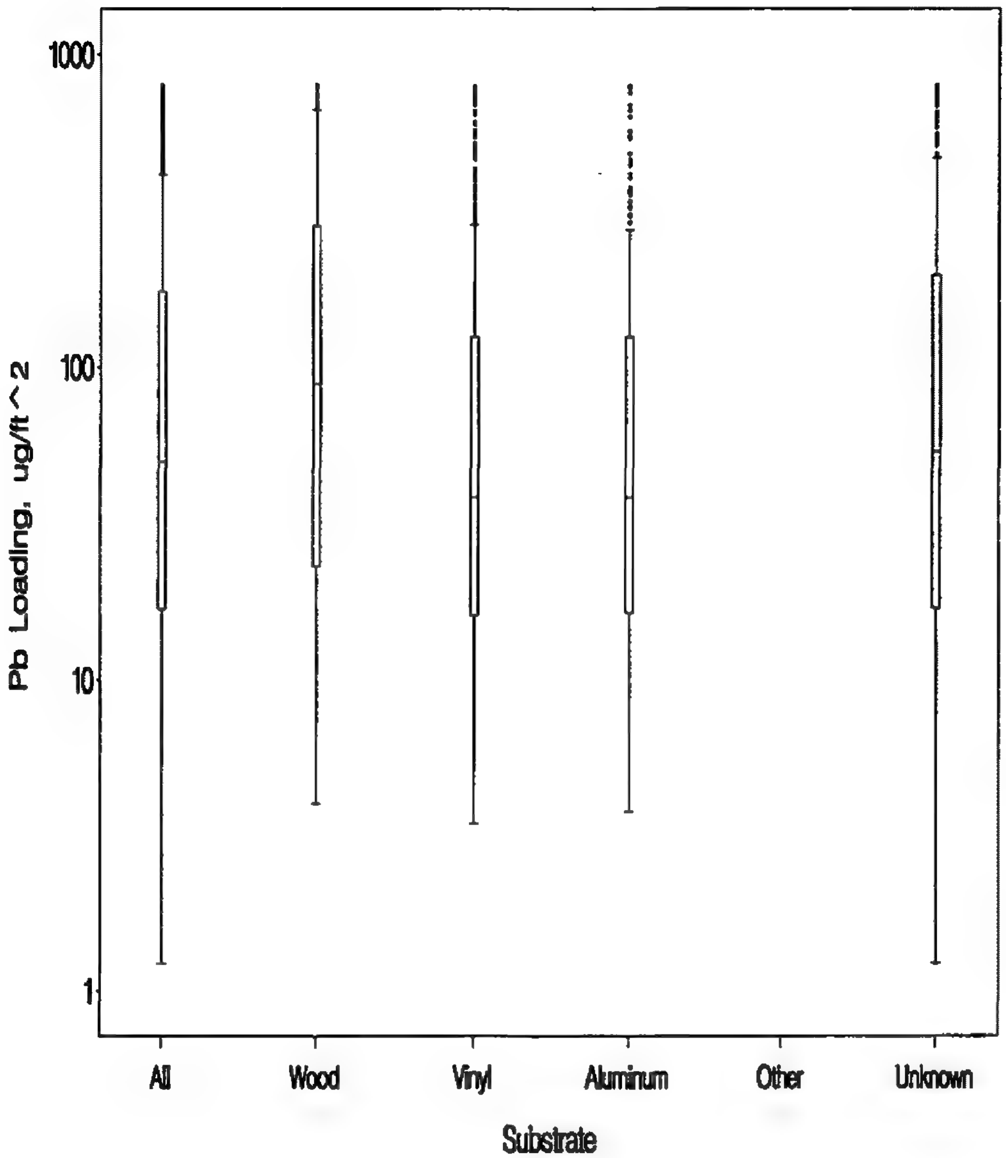

Figure E-8. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

Table E-3. Observed Within-Room Correlation Coefficients between Pb Loading Measurements Collected from Floors, Window Sills and Troughs for the Atlantic City Data.

Site Visit	Observed Within-Room Correlation Coefficients Between			
	Floors and Window Sills		Floors and Window Troughs	
	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n
First	0.32	26	0.65[a]	33
Second	.	.	0.10	8

[a] Statistically significantly different from zero at the 0.01 level.

measurements of individual floor, window sill, and window trough samples taken within the same room. The correlation between window sill samples and window trough samples was not able to be estimated due to insufficient data. In fact, for this data set, there were few cases where multiple samples were taken per room. The data from the first site visit show that correlation between floors and troughs is positive and significant at the 0.01 level. The correlation between floors and sills was estimated to be positive but was not statistically significantly different from zero. The correlation from the second site visit is difficult to interpret because of the small number of samples from which it was estimated.

The conditional probabilities of a sample passing or failing a standard are given in Table E-4. These analyses were intended to conduct on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed. However, no such results were observed in the Atlantic City data for the second subset of data. Window sill and window trough samples were not simultaneously present in rooms in this data set.

As shown in Table E-4, results from contingency table estimates and normal theory estimates are consistent for the left side of the table, but less so for the right side. For both types of estimates, the probability that one component passes clearance given that another component passes clearance is quite high (over 88%). The probability that one component fails clearance testing given that another component in the same room fails clearance testing ranged from 0% to 51%.

Table E-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
$P(F<200 \mid S<500)$	0.956	.	0.998	.	$P(F \geq 200 \mid S \geq 500)$	0.000	.	0.009	.
$P(S<500 \mid F<200)$	0.880	.	0.957	.	$P(S \geq 500 \mid F \geq 200)$	0.000	.	0.232	.
$P(F<200 \mid T<800)$	0.935	.	0.960	.	$P(F \geq 200 \mid T \geq 800)$	0.000	.	0.506	.
$P(T<800 \mid F<200)$	0.935	.	0.995	.	$P(T \geq 800 \mid F \geq 200)$	0.000	.	0.106	.

E-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

Simulated composite sample results were constructed from individual sample lead loading results from each component type within a residential unit. These simulated composite samples were then used to evaluate the three composite sample clearance criteria (Standard, Standard/n, and 2×Standard/n).

Table E-5 displays the number of residential units that were tested by the number of individual samples that were collected and each component type. For example, there were 57 residential units for which two dust-wipe samples were collected from floors on the first site visit. Residential units containing more than four samples from a particular component type resulted in the estimation of multiple simulated composite sample results in this analysis. Therefore, summing all the units that had five or more individual samples, approximately 25% (40/159), 5% (1/20), and 1% (1/119) of the residential units resulted in the estimation of multiple simulated composite samples from floors, window sills, and window troughs, respectively. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples.

For each component type within a residential unit, the set of individual clearance sample lead loading results were used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria For each combination of component type and composite clearance criterion, Table E-6 gives the number of residential units that either passed clearance, failed clearance, or yielded inconclusive results based on the composite clearance samples. Inconclusive results could only occur in a residential unit if more than four individual samples were collected from that unit. They occur due to the many possible ways of combining five (or more) individual samples into composite samples. For floor samples, the percentages of residential units with greater than four individual clearance samples that actually resulted in inconclusive results were 15% (6/40), 7.5% (3/40), and 17.5% (7/40) for the Standard, Standard/n, and 2×Standard/n Rules, respectively. No window sill or window trough composite sample yielded inconclusive results for any of the three criteria, and, of course, for each of these components, there was only on unit with more than four individual clearance samples.

Table E-5. Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data From the Atlantic City Housing Authority.

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	3	3	14
2	57	9	79
3	33	3	19
4	26	4	6
5	23	1	1
6	10	0	0
7	2	0	0
8	2	0	0
9+	3	0	0
Total	159	20	119
Total with N≥5	40	1	1

Table E-6. Individual Sample Clearance Results Versus Simulated Composite Clearance Results Based on Data from the Atlantic City Housing Authority.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	127	16	16	3	114	1
	Inconclusive	0	6	0	0	0	0
	Fail	0	10	0	1	0	4
Standard/n	Pass	119	0	15	0	109	0
	Inconclusive	3	0	0	0	0	0
	Fail	5	32	1	4	5	5
2 x Standard/n	Pass	126	4	15	2	111	0
	Inconclusive	1	6	0	0	0	0
	Fail	0	22	1	2	3	5

The performance characteristics of each combination of component type and composite clearance criteria are presented in Table E-7 in terms of sensitivity, specificity, positive

Table E-7. Performance Characteristics of Composite Clearance Criteria Based on Data from the Atlantic City Housing Authority.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2×Standard/n
Floors	Sensitivity	0.31	1.00	0.69
	Specificity	1.00	0.94	0.99
	PPV	1.00	0.87	1.00
	NPV	0.89	1.00	0.97
Window Sills	Sensitivity	0.25	1.00	0.50
	Specificity	1.00	0.94	0.94
	PPV	1.00	0.80	0.67
	NPV	0.84	1.00	0.88
Window Troughs	Sensitivity	0.80	1.00	1.00
	Specificity	1.00	0.96	0.97
	PPV	1.00	0.50	0.63
	NPV	0.99	1.00	1.00

predictive value (PPV), and negative predictive value (NPV). By design, the specificity of the Standard Rule is always 1.00 and the sensitivity of the Standard/n Rule is 1.00. So, in some sense, the Standard Rule sacrifices sensitivity for specificity while the Standard/n Rule sacrifices specificity for sensitivity. The 2×Standard/n Rule attempts to find a balance between these two criteria. For this data, the Standard Rule's sensitivity is estimated to be 0.31 for floors, 0.25 for window sills, and 0.80 for window troughs. The 2×Standard/n Rule seems to perform much better in terms of sensitivity with estimates of 0.69, 0.50, and 1.00 for floors, window sills and window troughs, respectively. The estimates of sensitivities for window sills and window troughs, however, are based on very few units which failed individual sample clearance testing. The 2×Standard/n Rule seems to perform quite well in terms of specificity with estimates of 0.99 for floors, 0.94 for window sills, and 0.97 for window troughs. When comparing the overall performance of the three criteria in this case, the Standard/n Rule seems to perform quite well both in terms of sensitivity and specificity.

It is evident that all three composite clearance testing criteria have different sensitivities and specificities associated with their application to the simulated composite samples. In order to further investigate the performance of each of the three composite clearance criteria, the following logistic regression model was fitted for each combination of component type and composite clearance criterion to describe the relationship between the probability of passing clearance based on composite samples and the maximum lead loading present in the individual samples collected:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

For each component type, the estimated relationship between the probability of passing clearance and the maximum lead loading is presented in Figure E-9. Note that the relationship could not be estimated for window troughs using the Standard Rule due to the nature of the data. Under this rule, the observed data were such that at a given level the unit passed, and at a given level the sample failed. Estimation problems arise when trying to estimate the relationship *between* these two levels. An infinite number of curves could be fit to estimate the relationship between the two levels, but there is no criterion to choose the optimal one. Therefore, the relationship cannot be estimated for this rule.

Table E-8 provides parameter estimates and associated standard errors from the logistic regression models, as well as estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2, and 4 times the associated interim HUD standard for individual samples. The low sensitivity of the Standard Rule is illustrated by the high (73%) estimated probability of a unit passing clearance testing based on floor composite samples and a maximum individual sample lead-loading of 2×HUD standard. Conversely, the estimated probability of passing based on floor composite samples using the 2×Standard/n Rule is estimated to be only about 1% at 2 times the HUD standard. The lower specificity of the Standard/n Rule is exhibited by the 89% estimated probability of a floor composite sample passing based on an individual maximum lead loading of one-half the HUD standard, compared

to probabilities of 0.98 and 1.00 for the other two decision rules. The estimates for window troughs at one-half the HUD standard are similar to those for floors, but the estimates of the probabilities of passing with a maximum individual sample lead loading at the HUD standard are much lower for the 2×Standard/n Rule and somewhat lower for the Standard/n Rule. This most likely reflects the difference in the relationships among the window trough samples collected from a unit compared to the relationships of floor samples collected within a unit. The estimates of the probabilities for window sills should be viewed with caution due to the small number of samples involved.

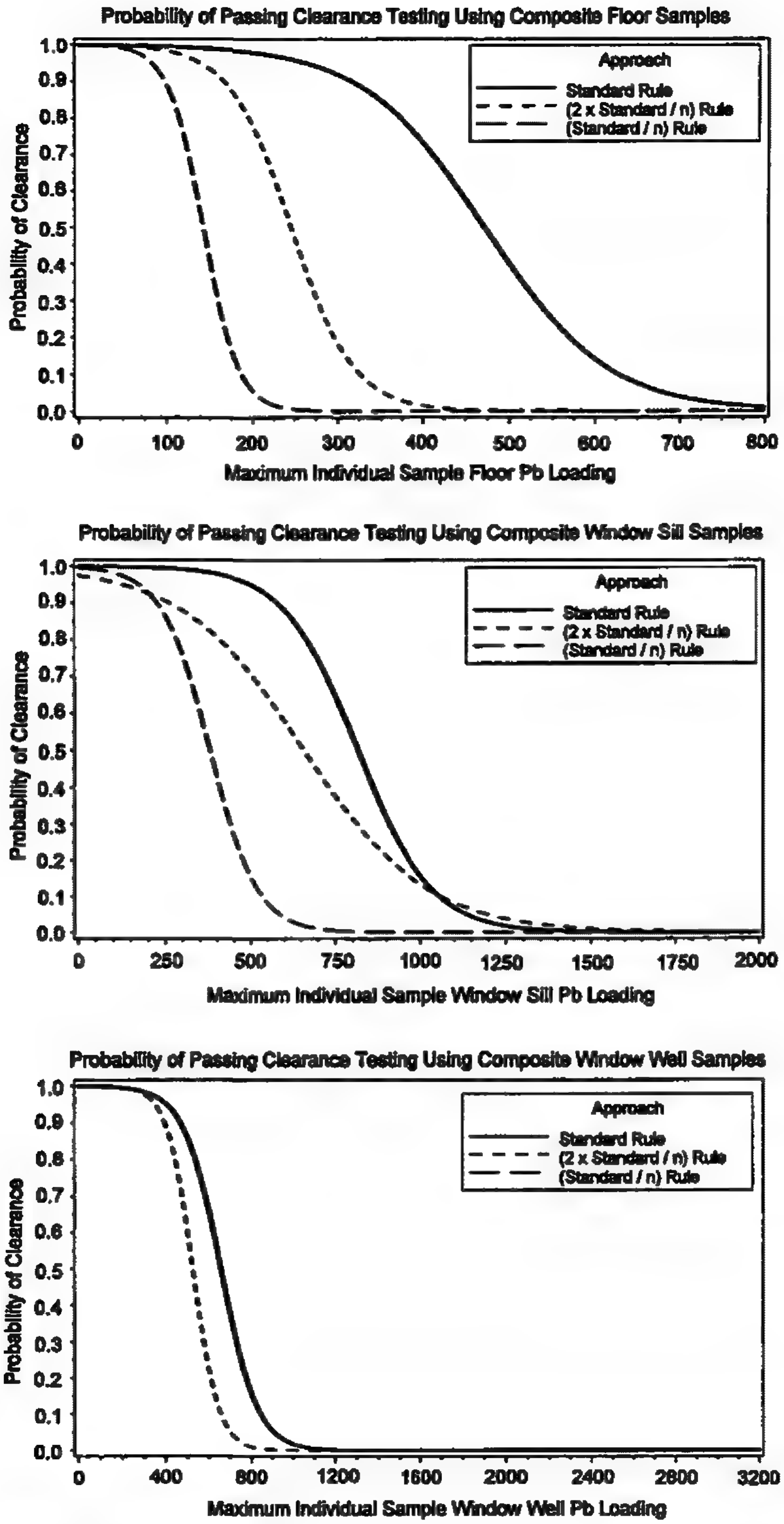

Figure E-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Result by Component Type Based on Simulated Composite Samples from the Atlantic City Housing Authority.

Table E-8. Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, Under Three Different Composite Sampling Decision Rules, Using Data from the Atlantic City Housing Authority.

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance When the Maximum Individual Sample Result Within a House is Equal to			
		Pass	Inconclusive	Fail	β_0	s.e.(β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Floors	Standard	143	6	10	6.654	1.512	-0.014	0.004	1.00	0.98	0.73	0.01
	2 x Standard/n	130	7	22	6.749	1.480	-0.028	0.006	0.98	0.78	0.01	0.00
	Standard/n	119	3	37	7.018	1.477	-0.050	0.012	0.89	0.05	0.00	0.00
Window Sills	Standard	19	0	1	7.509	6.052	-0.009	0.009	1.00	0.95	0.16	0.00
	2 x Standard/n	17	0	3	3.613	1.454	-0.006	0.003	0.90	0.70	0.13	0.00
	Standard/n	15	0	5	5.362	2.566	-0.014	0.007	0.86	0.15	0.00	0.00
Window Troughs	Standard	115	0	4	.	.	.	.	.		.	.
	2 x Standard/n	111	0	8	7.623	2.700	-0.012	0.004	0.95	0.16	0.00	0.00
	Standard/n	109	0	10	8.752	3.520	-0.016	0.007	0.89	0.01	0.00	0.00

APPENDIX F

Cleveland Lead Hazard Abatement Center

APPENDIX F

CLEVELAND LEAD HAZARD ABATEMENT CENTER

The lead abatement program managed by the Cleveland Lead Hazard Abatement Center recruited houses where children with elevated blood lead levels lived [19]. Most of the units were large single-family houses built before 1950. The level of intervention depended on the age and number of children in the house. The homes had a mix of interim controls and abatement treatments. Chipped paint was scraped and repainted with a primer and a coat of paint. Carpets were removed and the floors were either repaired, covered with plywood, or refinished. Windows were replaced in some units. Vinyl siding was applied to homes with lead-based painted wood siding. Porches were repaired, deteriorated sections replaced, and other surfaces scraped and repainted. Lead contaminated soil was generally covered with sod, wood chips, or some other form of landscape cover; if lead contamination was extremely high, soil was removed and replaced. This project is ongoing. Results for window trough, window sill, and floor wipe samples collected from each room in the unit were analyzed.

F-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

As part of clearance testing within the Cleveland Lead Hazard Abatement Center's intervention program, 312 individual dust wipe samples were collected from floors, window sills, and window troughs within 196 rooms in 38 residential units from December 1993 through May 1995. Table F-1 presents the number of individual samples, work areas, and residential units that passed or failed clearance testing within each combination of component type and site visit. Approximately 93% (290/312) of the dust samples were collected during the first site visit to a residential unit. Although 92% (267/290) of the dust samples fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs, and 88% (173/196) of the rooms passed clearance on the first site visit, only 61% (23/38) of the residential units passed clearance on the first site visit. This increase in the failure rate from the percentage of individual samples and rooms that fail to the percentage of residential units that fail is

Table F-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit for the Cleveland Lead Hazard Abatement Center.

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	138	20	158	137	20	157	24	14	38
	Sill	92	1	93	92	1	93	32	1	33
	Trough	37	2	39	37	2	39	22	2	24
	All	267	23	290	173	23	196	23	15	38
Second	Floor	15	3	18	15	3	18	10	3	13
	Sill	1	0	1	1	0	1	1	0	1
	Trough	2	0	2	2	0	2	2	0	2
	All	18	3	21	18	3	21	11	3	14
Third	Floor	1	0	1	1	0	1	1	0	1
	All	1	0	1	1	0	1	1	0	1
Total	Floor	154	23	177	153	4	157	35	3	38
	Sill	93	1	94	93	0	93	33	0	33
	Trough	39	2	41	39	0	39	24	0	24
	All	286	26	312	192	4	196	35	3	38

attributable to the fact that if any individual sample exceeds the standard and fails clearance, then the residential unit also fails clearance. Of the 15 residential units that failed clearance on the first site visit, 14 (93%) of these residential units were revisited for a second clearance testing. Seventy-nine percent (11/14) of the units passed clearance on the second site visit. Of the three units that did not pass clearance on the second visit, one passed clearance after a third visit. Thus, at the time the data for this report were collected, 35 of the 38 residential units (92%) had passed clearance testing.

The failure rate for individual samples during the first site visit was higher for floor samples (13% (20/158)) than that for window troughs (5% (2/39)) or window sills (1% (1/93)). This pattern is reflected in the failure rates for residential units based on results from individual components: 37% (14/38) of the residential units failed based on the results of floor samples, 8%

(2/24) of the residential units failed based on the results of window trough samples, and 3% (1/33) of the residential units failed based on the results of window sill samples.

F-2. Objective 2: Characterization of the Distribution of the Dust-Lead Loadings, Geometric Mean Dust-Lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

The Cleveland program had the fewest number of residential units tested for clearance. The number of samples collected during the second site visit was very small. The geometric mean for the floor clearance samples was less than the window sills which was less than the window troughs for the first site visit. However, they were not statistically different from one another. For the first site visit, the estimated within components of variances are greater than the between components for floors and window sills; the opposite is true for window troughs.

Figures F-1 and F-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures F-3 to F-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures F-6 to F-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

F-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships among floor, window sill, and window trough wipe samples are another important aspect of examining a clearance testing program. One method of assessing the relationships among individual floor, window sill, and window trough wipe samples collected from the same room is to estimate linear correlation coefficients. Table F-3 displays the Pearson product-moment correlation coefficients and the associated sample size for the log lead loading measurements of individual floor, window sill, and window trough samples taken within the same room. The correlation between window sills and window troughs is the highest of any observed correlation but it is not statistically significant. None of the observed correlations are statistically significantly different from zero at the 0.05 level.

Table F-2. Clearance Testing Geometric Mean and Variance Component Estimates by Site Visit and Component Type for the Cleveland Data Set.

Site Visit	Component Tested	# of Individual Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	158	157	38	29.7	0.67	1.05	22.4	39.3
	Sill	93	93	33	37.8	0.81	0.86	26.7	53.6
	Trough	39	39	24	44.7	1.45	1.00	22	90.9
Second	Floor	18	18	13	29.4	1.29	0.38	13.1	65.8
	Sill	1	1	1	1.0	.	.	.	.
	Trough	2	2	2	403	0.16	0.38	9.6	16800
Third	Floor	1	1	1	1.0	.	.	.	.

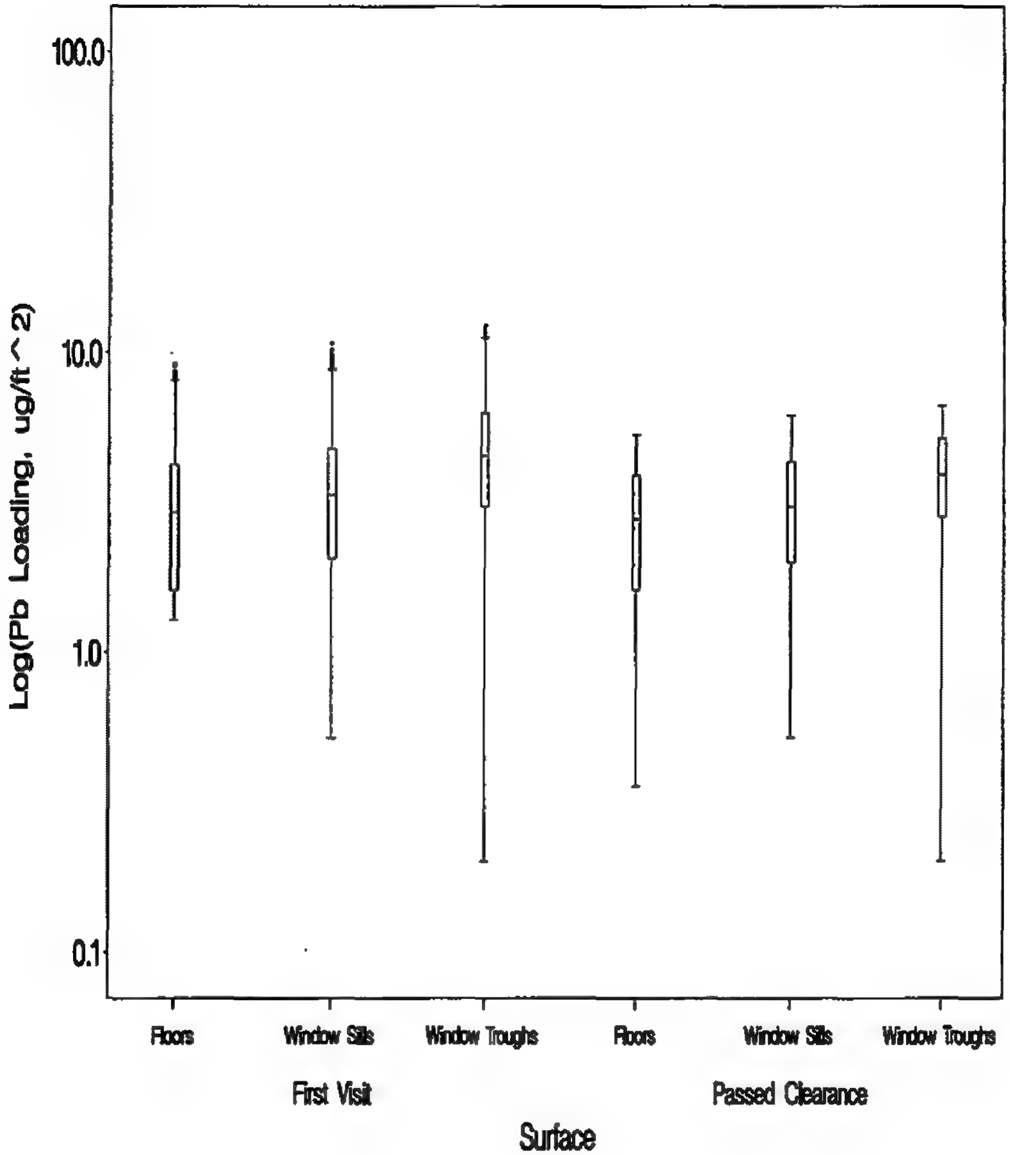

Figure F-1. **Comparison of ln-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.**

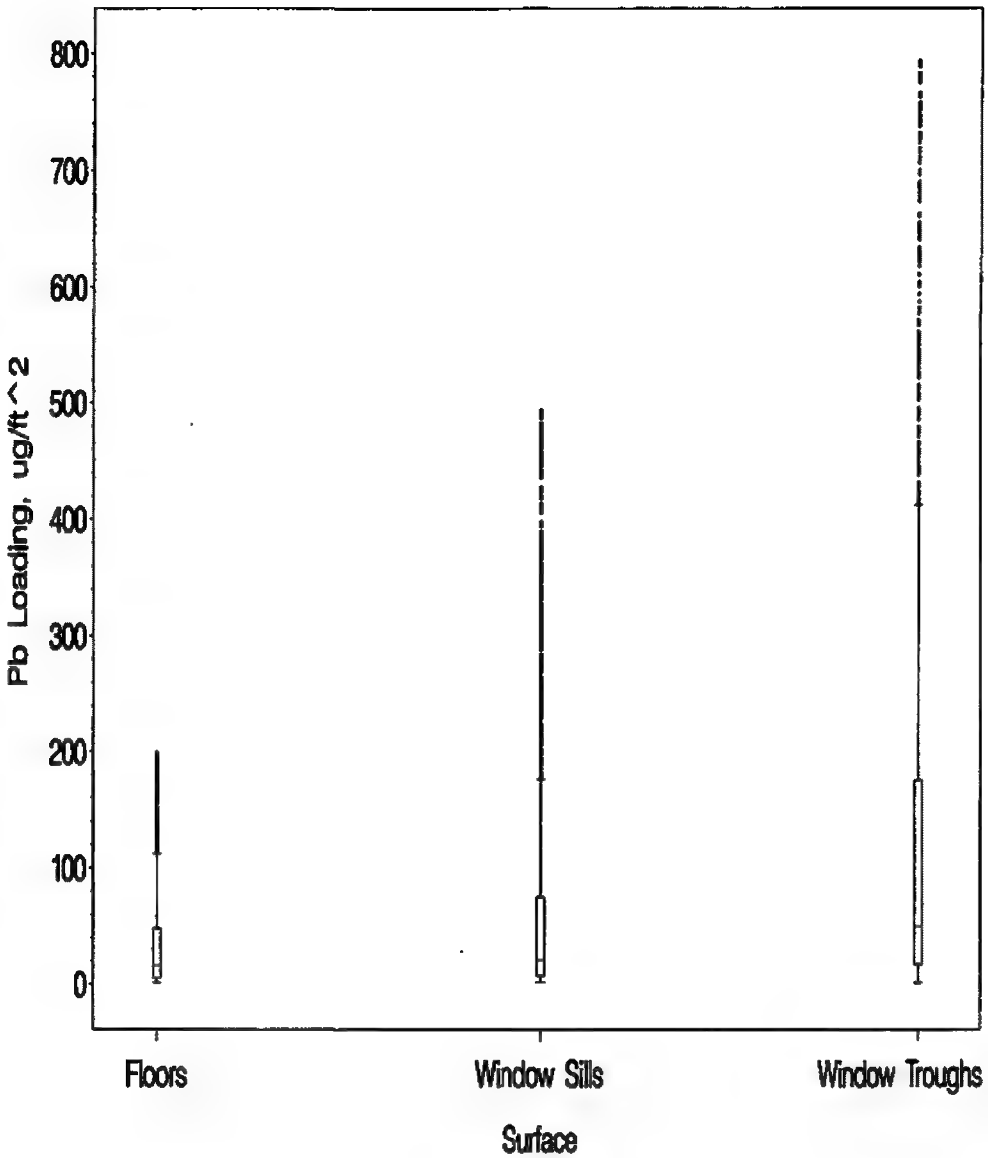

Figure F-2. **Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.**

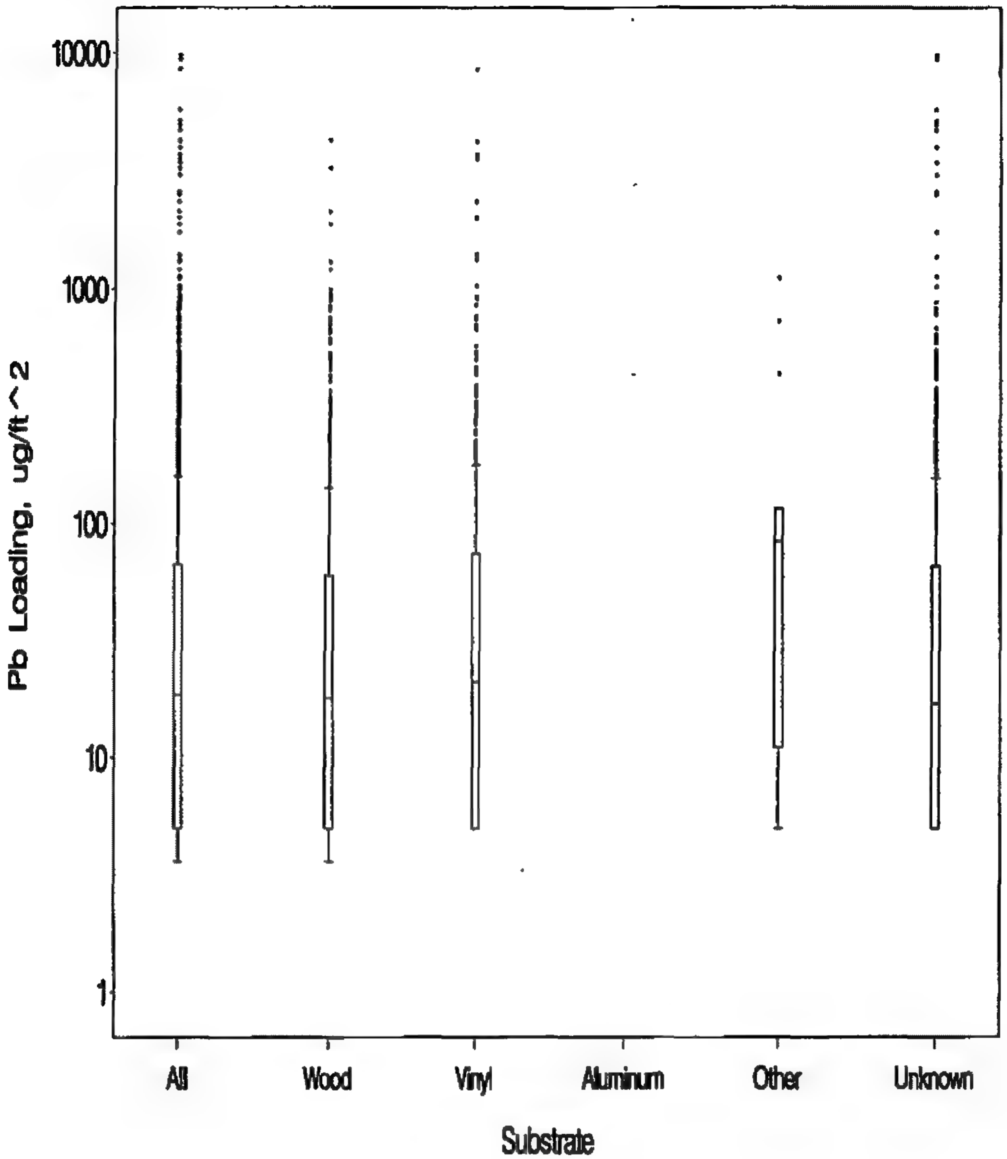

Figure F-3. **Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.**

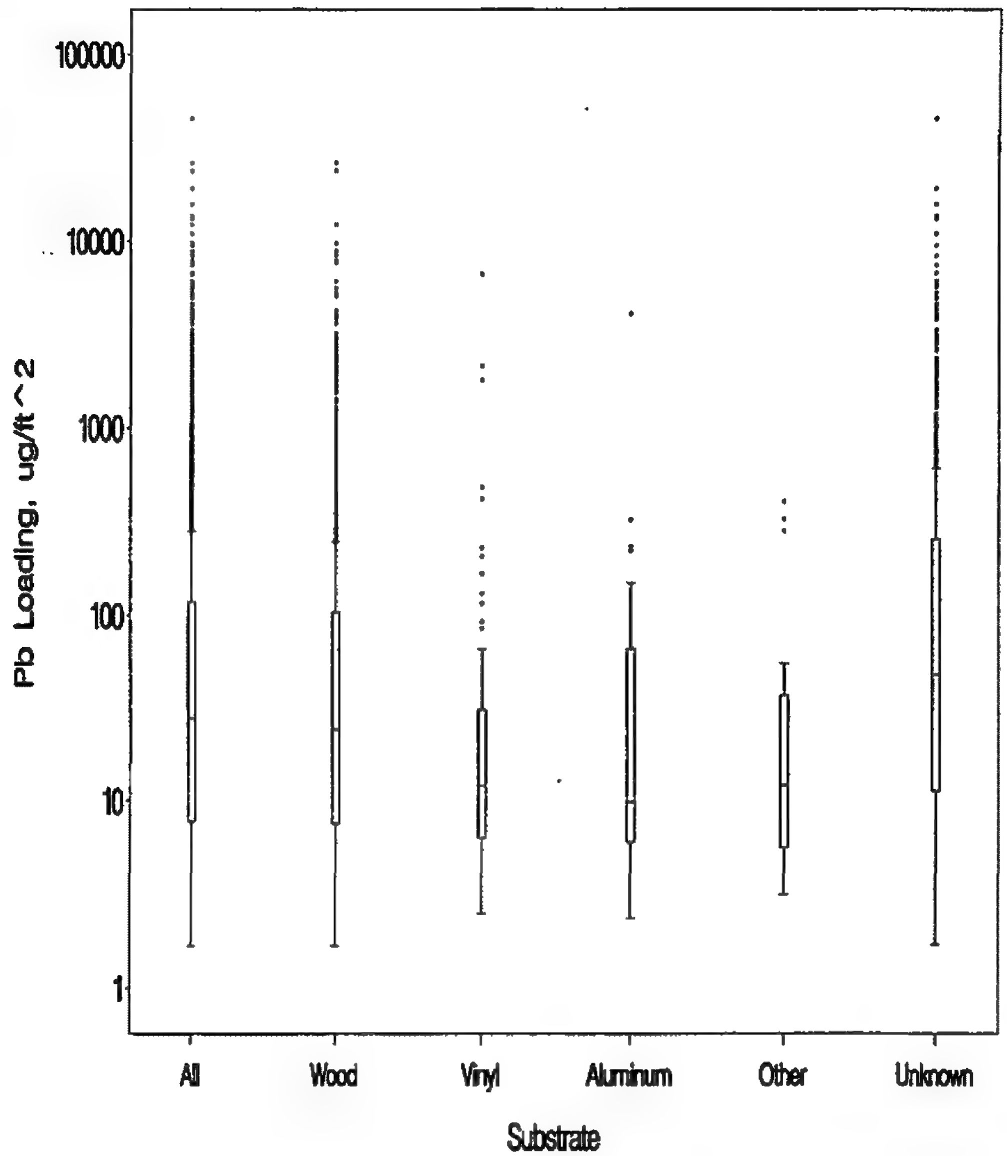

Figure F-4. **Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.**

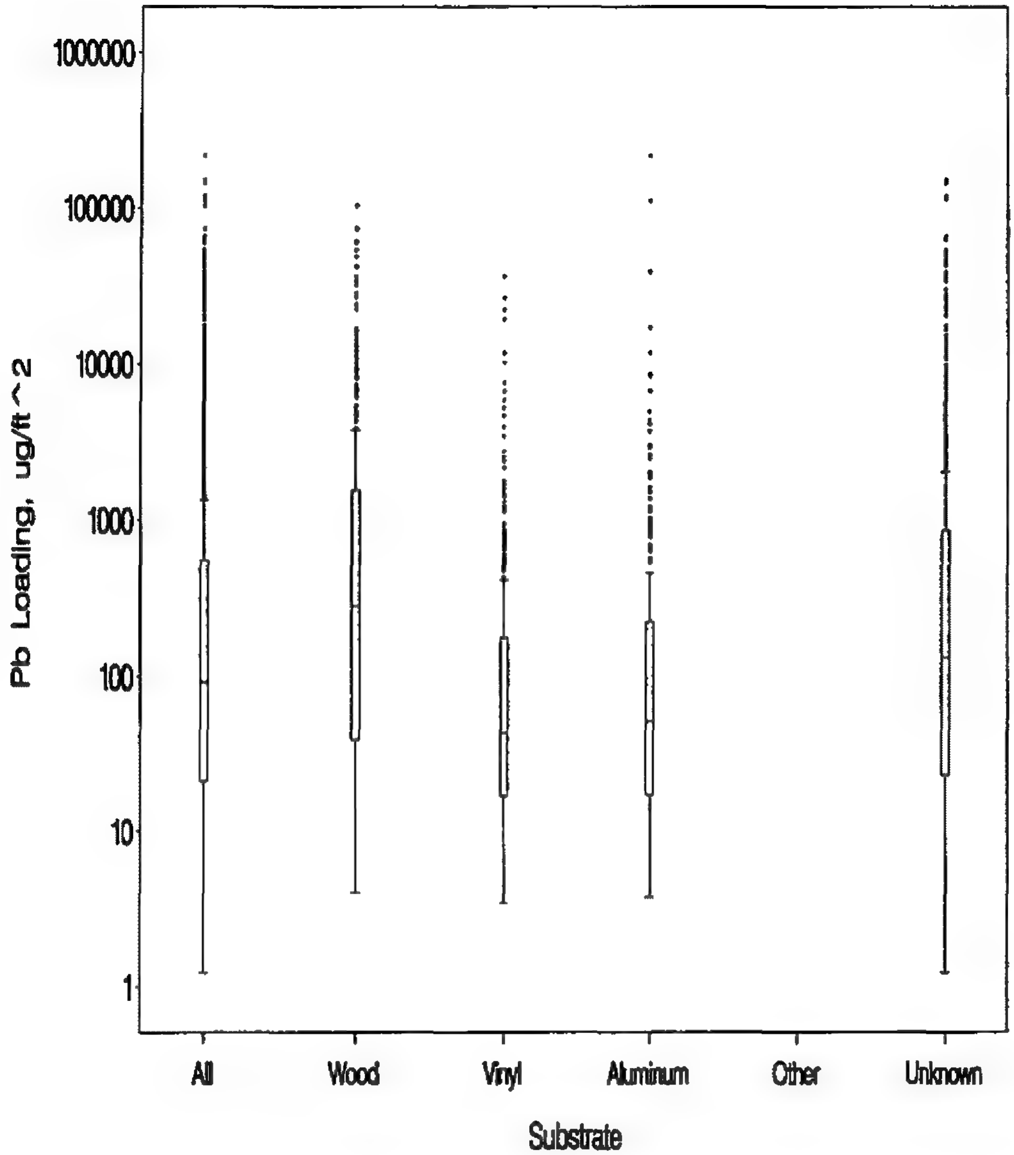

Figure F-5. **Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.**

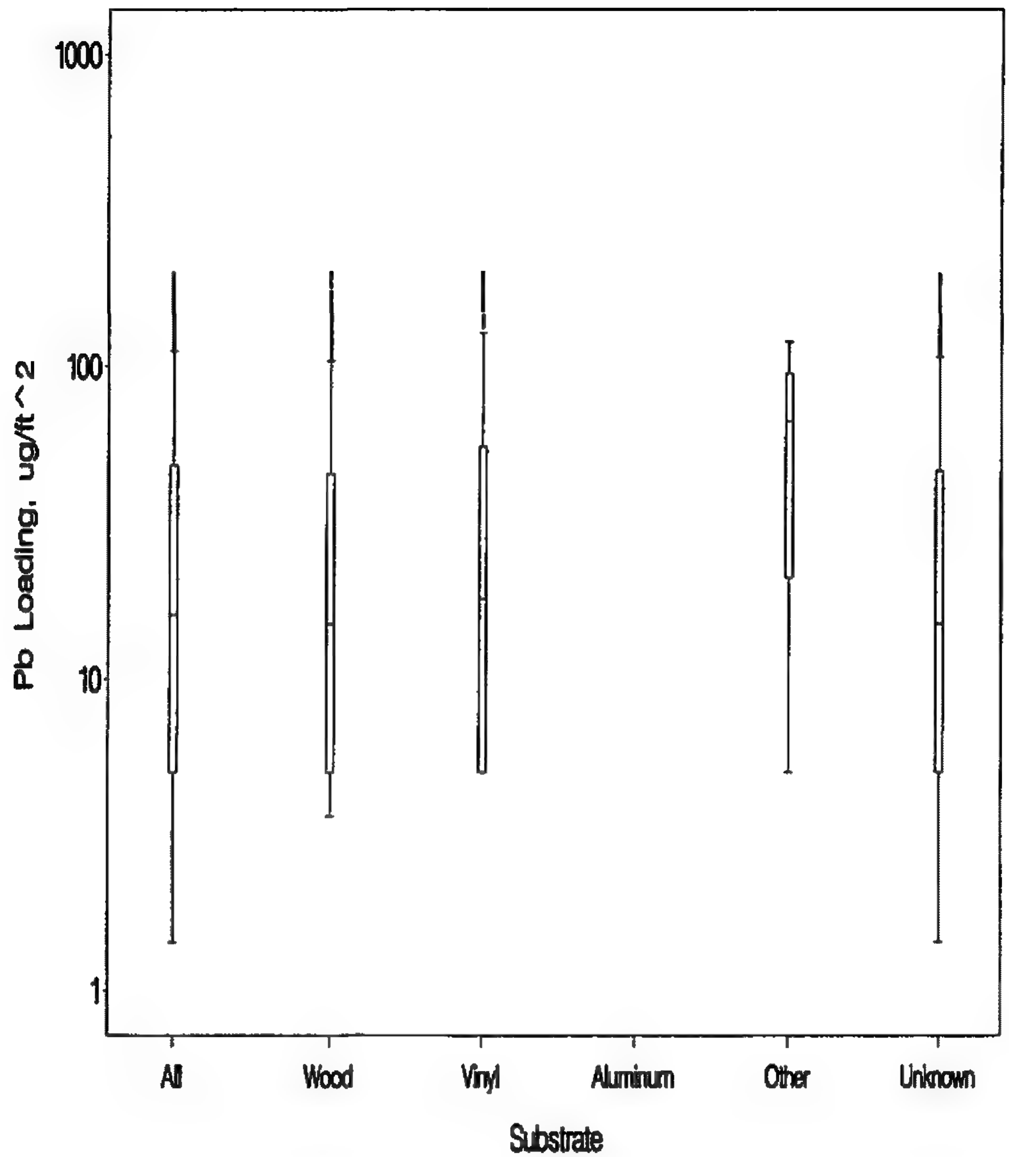

Figure F-6. **Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.**

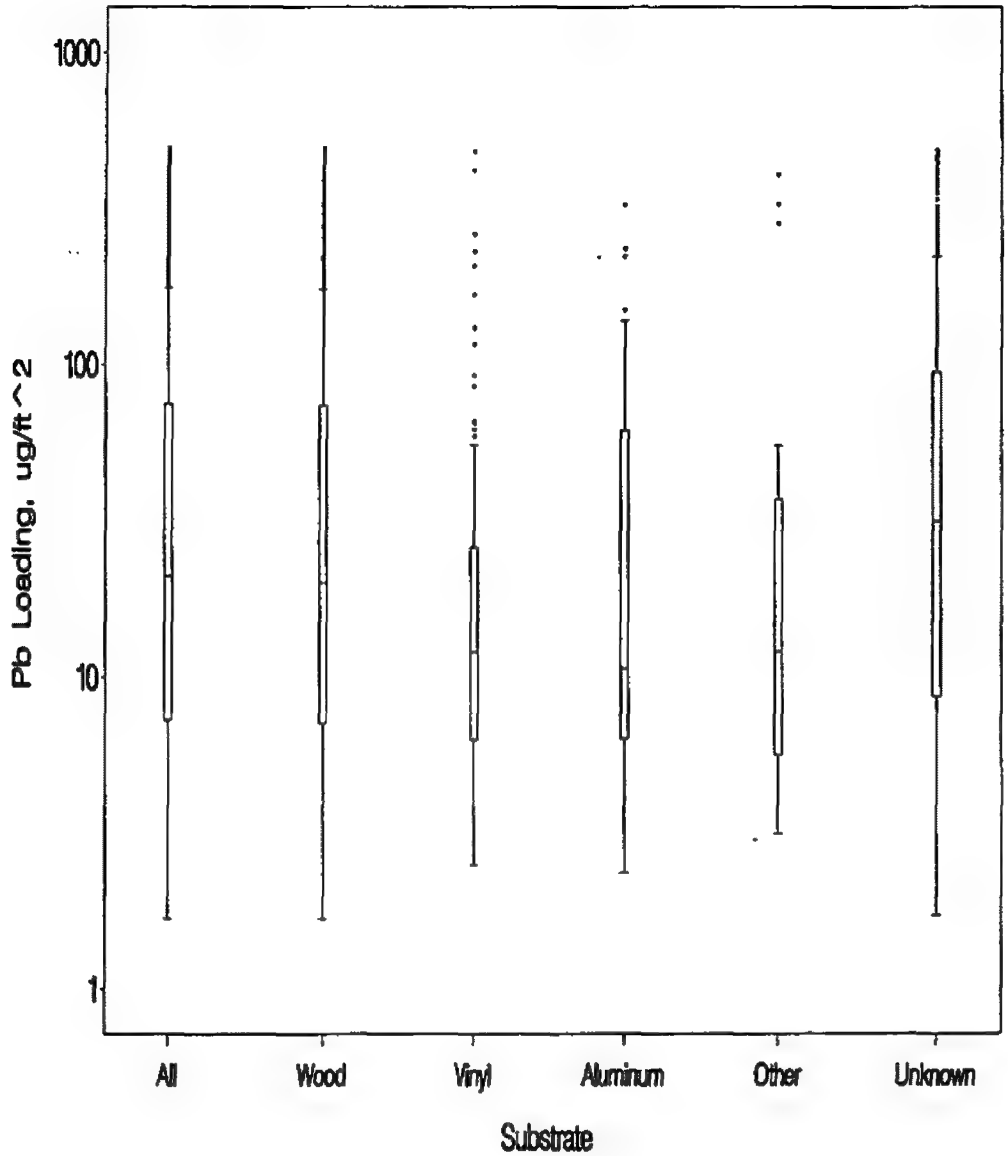

Figure F-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

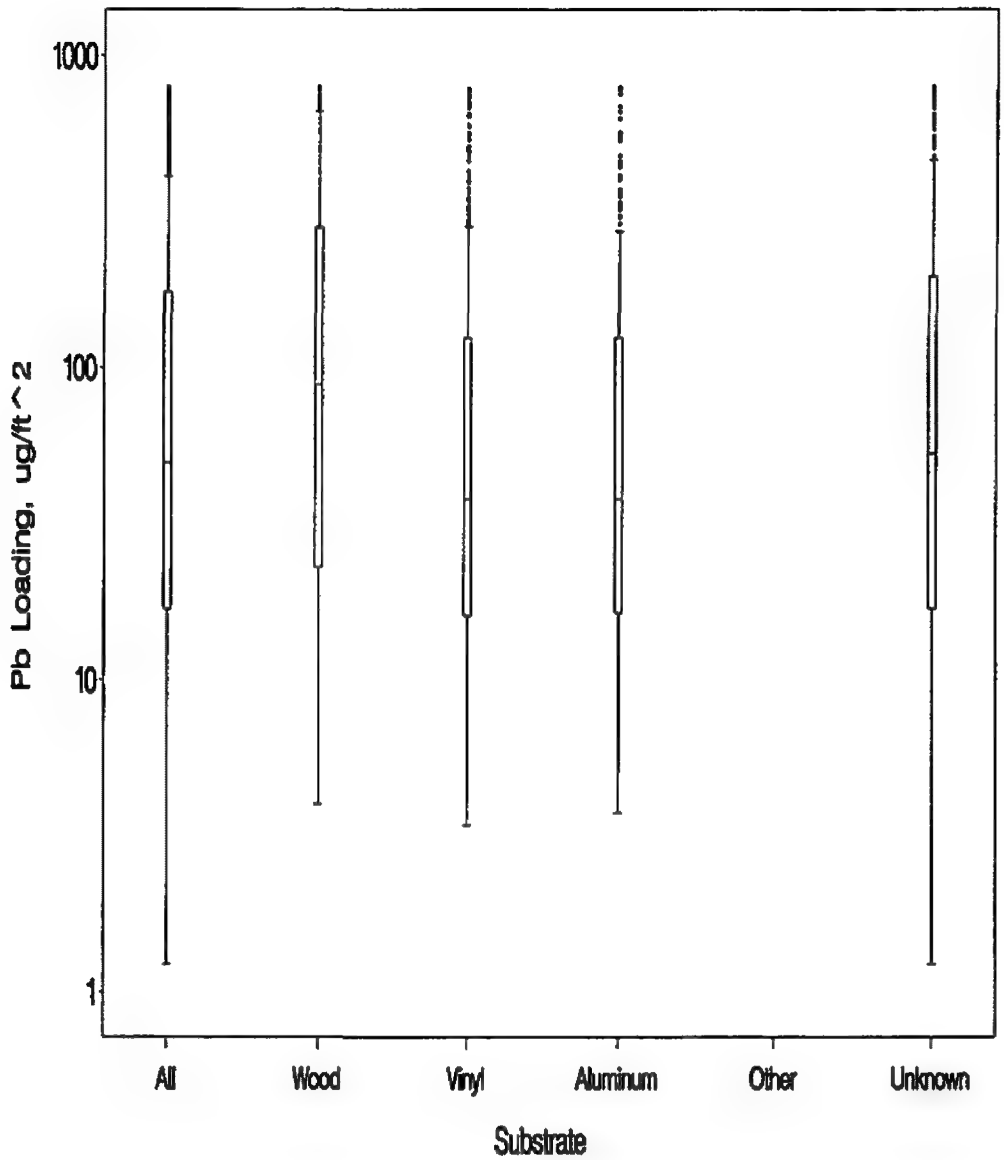

Figure F-8. **Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.**

Table F-3. Observed Within-Room Correlation Coefficients between Pb Loading Measurements Collected from Floors, Window Sills and Troughs for the Cleveland Data.

Site Visit	Observed Within Room Correlation Coefficients Between					
	Floors and Window Sills		Floors and Window Troughs		Window Sills and Troughs	
	$\rho_{Floors\ Sills}$	n	$\rho_{Floors\ Troughs}$	n	$\rho_{Sills\ Troughs}$	n
First	0.14	64	0.30	24	0.47	13

The conditional probabilities of a sample passing or failing a standard are given in Table F-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed.

As shown in Table F-4, results from contingency table estimates and normal theory estimates are consistent, although more so on the left side of the table than on the right. For both types of estimates and both data sets included in the analysis, the probability that one component passes clearance given that another component passes clearance is quite high (over 88%), while the probability that one component fails clearance testing given that another component in the same room fails clearance testing is low (mostly under 26%).

F-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

Individual sample lead loading results from each component type within a residential unit were combined to construct simulated composite sample results.

Table F-5 provides the number of residential units that were investigated by the number of individual samples that were collected for each component type. For example, there were 6 residential units which included four window sill dust-wipe samples on the first site visit. Residential units containing more than four samples from a component type resulted in the estimation of multiple simulated composite sample results in this analysis. Therefore, approximately 37% (14/38) of the residential units had five or more samples and resulted in the

Table F-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
P(F<200|S<500)	0.921	0.875	0.951	0.930	P(F≥200|S≥500)	.	.	0.095	0.234
P(S<500|F<200)	1.000	1.000	0.994	0.983	P(S≥500|F≥200)	0.000	0.000	0.012	0.067
P(F<200|T<800)	0.956	0.875	0.984	0.936	P(F≥200|T≥800)	0.000	.	0.121	0.253
P(T<800|F<200)	0.956	1.000	0.967	0.962	P(T≥800|F≥200)	0.000	0.000	0.111	0.163
P(F<500|T<800)	1.000	1.000	0.986	0.990	P(F≥500|T≥800)	.	.	0.108	0.229
P(T<800|S<500)	1.000	1.000	0.963	0.963	P(T≥800|S≥500)	.	.	0.253	0.532
P(F<200|S<500,T<800)	.	0.875	.	0.937	P(F≥200|S≥500,T≥800)	.	.	.	0.297
P(S<500|F<200,T<800)	.	1.000	.	0.991	P(S≥500|F≥200,T≥800)	.	.	.	0.269
P(T<800|F<200,S<500)	.	1.000	.	0.969	P(T≥800|F≥200,S≥500)	.	.	.	0.675

estimation of multiple simulated composite samples from floors. Conversely, only 9% (3/33) of the units which had window sill samples collected and none of the residential units which had window trough samples collected resulted in the estimation of multiple simulated composite samples. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples.

Table F-5. Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data From the Cleveland Lead Hazard Abatement Center.

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	0	7	14
2	1	4	6
3	13	13	3
4	10	6	1
5	10	3	0
6	3	0	0
7	0	0	0
8	0	0	0
9+	1	0	0
Total	38	33	24
Total with N≥5	14	3	0

For each component type within a residential unit, the set of individual clearance sample lead loading results was used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria (Standard, Standard/n, and 2×Standard/n). For each combination of component type and composite clearance criterion, Table F-6 indicates the number of residential units that either passed clearance, failed clearance, or yielded inconclusive results. The percentage of residential units that had more than four individual samples for a particular component which actually resulted in inconclusive results was

low (no more than 5.3% for any given combination of component type and clearance criterion) for this data set.

Table F-6. Individual Sample Clearance Results Versus Simulated Composite Clearance Results Based on Data from the Cleveland Lead Hazard Abatement Center.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	27	7	32	0	22	0
	Inconclusive	0	2	0	0	0	0
	Fail	0	2	0	1	0	2
Standard/n	Pass	20	0	30	0	22	0
	Inconclusive	2	0	1	0	0	0
	Fail	5	11	1	1	0	2
2 × Standard/n	Pass	26	3	32	0	22	0
	Inconclusive	1	0	0	0	0	0
	Fail	0	8	0	1	0	2

The performance characteristics of each combination of component type and composite clearance criteria are presented in Table F-7 in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). These performance characteristics attempt to estimate the false negative and false positive error rates for the different clearance criteria.

The Standard/n Rule is formulated such that specificity is always sacrificed for sensitivity. The sensitivity for the Standard/n Rule is always 1.00 while the specificity for this rule is estimated to be 0.74 for floors, 0.94 for window sills, and 1.00 for window troughs. On the other hand, the Standard Rule is designed so that it always sacrifices sensitivity for specificity. The specificity for the Standard Rule is always 1.00 while the sensitivity for this rule is estimated at 0.18 for floors, 1.00 for window sills, and 1.00 for window troughs. For the 2×Standard/n Rule, the values of sensitivity are higher than or equal to those calculated for the Standard Rule, while the values of specificity are higher than or equal to those calculated for the Standard/n Rule. Estimates of sensitivity and specificity in these examples are always

Table F-7. Performance Characteristics of Composite Clearance Criteria Based on Data from the Cleveland Lead Hazard Abatement Center.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2 x Standard/n
Floors	Sensitivity	0.18	1.00	0.73
	Specificity	1.00	0.74	0.96
	PPV	1.00	0.69	1.00
	NPV	0.79	1.00	0.90
Window Sills	Sensitivity	1.00	1.00	1.00
	Specificity	1.00	0.94	1.00
	PPV	1.00	0.50	1.00
	NPV	1.00	1.00	1.00
Window Troughs	Sensitivity	1.00	1.00	1.00
	Specificity	1.00	1.00	1.00
	PPV	1.00	1.00	1.00
	NPV	1.00	1.00	1.00

conservative, because inconclusive composite test results factor into the denominator for each inconclusive composite test results factor into the denominator for each estimate, but never factor into the numerator.

It is evident that all three composite clearance testing criteria have different sensitivities and specificities associated with their application to the simulated composite samples. To evaluate the performance of each of the three composite clearance criterion in another manner, the following logistic regression model was fitted for each combination of component type and composite clearance criterion. The goal was to describe the relationship between the probability of passing clearance and the maximum lead loading present in all of the individual samples tested in a residential unit:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

The estimated relationship between the probability of passing clearance and the maximum lead loading for floors and window sills is presented graphically in Figure F-9. The relationship was not able to be estimated for floors using the 2×Standard/n Rule and for window sills using either the 2×Standard/n Rule or the Standard Rule because of the nature of the data. The data were such that, under the 2× Standard/n Rule for floors and under the 2×Standard/n Rule or the Standard/n Rule for window sills, at a given level the unit passed, and at a given level the sample failed. Estimation problems arose when trying to estimate the relationship between these two levels. An infinite number of curves could be fit to estimate the relationship between the two levels, but there is no criteria for choosing the optimal one. Therefore, the relationship could not be estimated. The data for window troughs present the same problem for all three of the clearance criteria, so no curves were fit to this component type.

Table F-8 provides parameter estimates and associated standard errors from the logistic regression models, as well as estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2, and 4 times the associated interim HUD standard for individual samples. The high sensitivity of the Standard/n Rule is evident by the low (61%) estimated probability of passing for floor samples with a maximum individual lead loading of one-half that of the HUD standard. For window sills, however, the probability is estimated to be 89% using the Standard/n Rule. The low sensitivity of the Standard Rule is displayed by the relatively high estimated probability (28%) of passing given that the maximum individual sample lead-loading is twice the HUD standard.

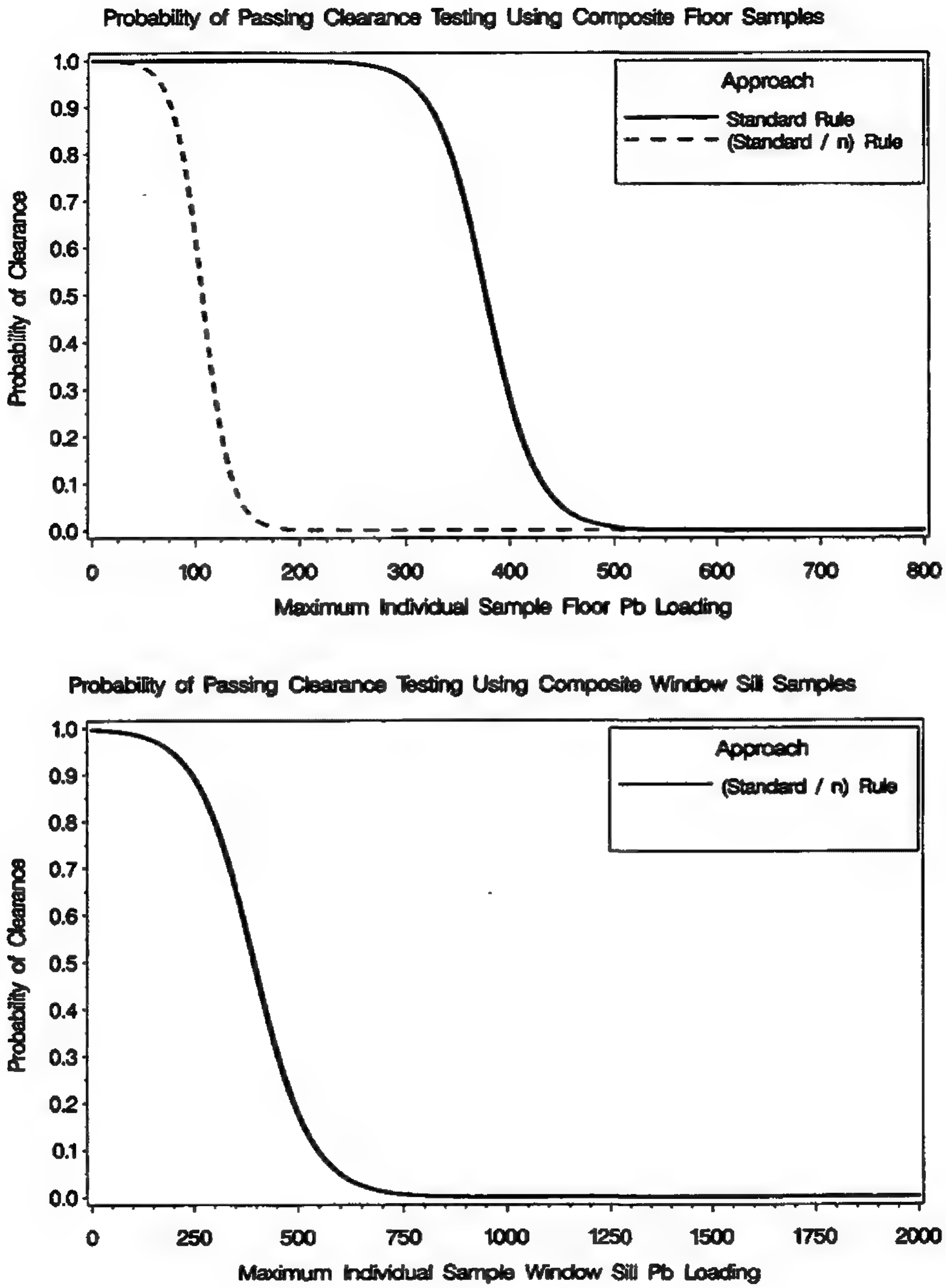

Figure F-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Result by Component Type Based on Simulated Composite Samples from Cleveland Lead Hazard Abatement Center.

Table F-8. Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, Under Three Different Composite Sampling Decision Rules, Using Data from the Cleveland Lead Hazard Abatement Center.

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance When the Maximum Individual Sample Result Within a House Is Equal to			
		Pass	Inconclusive	Fail	β_0	s.e.(β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Floors	Standard	34	2	2	15.39	11.072	-0.041	0.032	1.00	1.00	0.28	0.00
	2 × Standard/n	29	1	8	89.903	81.060	-0.288	0.259	1.00	1.00	0.00	0.00
	Standard/n	20	2	16	7.685	3.452	-0.072	0.036	0.61	0.00	0.00	0.00
Window Sills	Standard	32	0	1	.	.	.	.	.	.	.	.
	2 × Standard/n	32	0	1	.	.	.	.	.	.	.	.
	Standard/n	30	1	2	5.772	2.525	-0.015	0.009	0.89	0.18	0.00	0.00
Window Troughs	Standard	22	0	2	.	.	.	.	.	.	.	.
	2 × Standard/n	22	0	2	.	.	.	.	.	.	.	.
	Standard/n	22	0	2	.	.	.	.	.	.	.	.

APPENDIX G

Dover Housing Authority, New Hampshire

APPENDIX G

DOVER HOUSING AUTHORITY, NEW HAMPSHIRE

One-hundred and eighty-four units in 49 multi-family buildings were abated and renovated [20]. Forty-three of the buildings had four units per building and the other six buildings had two units per building. The exterior siding and window sashes of the buildings contained lead-based paint, so siding and windows including the sashes were removed and replaced. Interior lead-based paint was found only on water radiators. Thirty-one of the units had cast iron radiators. The radiators were removed from the apartments, sand blasted and repainted offsite, and reinstalled. Even though there was very limited abatement activity inside the units, dust wipe samples from the window troughs and sills along with floor samples were analyzed for lead clearance.

G-1. Objective 1: Characterization of the Number of Individual Samples, Work Areas, and Housing Units That Pass or Fail Clearance Testing Standards

The Dover Housing Authority tested all 184 units for clearance. Clearance data were made available for this analysis from 704 rooms in 158 of the 184 residential units that were abated and renovated. Nine-hundred and sixteen individual dust wipe samples were collected over a six month period of time, spanning from May 1992 through October 1992. Three different components were sampled with 633 samples (69%) being collected from floors, 18 samples (2%) from window sills and 265 samples (29%) from window troughs. Table G-1 presents the number of individual samples, work areas and residential units that passed or failed clearance testing within each combination of component type and site visit. All of the dust samples were collected during the first site visit to a residential unit. On the first site visit, 97% (891/916) of the individual dust samples fell below the clearance standards of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window troughs, 96% (679/704) of the rooms passed clearance and 87% (137/158) of the residential units met clearance standards. This increase in the failure rate from the percentage of individual samples and rooms that fail to the percentage of residential units that fail is attributable to the fact that if any individual sample exceeds the standard and fails clearance, then the residential unit from which it was taken also

Table G-1. Clearance Testing Results by Individual Sample, Room, and Residential Unit for the Dover Housing Authority.

Site Visit	Component Tested	Clearance Samples			Rooms Sampled			Houses Sampled		
		Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
First	Floor	620	13	633	610	13	623	140	11	151
	Sill	11	7	18	11	7	18	7	5	12
	Trough	260	5	265	256	5	261	141	5	146
	All	891	25	916	679	25	704	137	21	158
Total	Floor	620	13	633	610	13	623	140	11	151
	Sill	11	7	18	11	7	18	7	5	12
	Trough	260	5	265	256	5	261	141	5	146
	All	891	25	916	679	25	704	137	21	158

fails clearance. The residential units that failed clearance on the first site visit were revisited for a second clearance testing. The location of the failed test was recleaned and retested. All of the samples collected during retesting passed the clearance standards. The retesting data were not available. This report only analyzed the first site visit data.

The failure rate for individual samples was highest for window sill samples (39%), followed by floors (2.1%) and window troughs (1.9%). Floors were also the most densely sampled component with an average of 4.2 samples (633/151) taken per unit while 1.8 samples (265/146) were taken from window troughs per unit. Among 158 housing units which were included in the Dover data, only 12 housing units had window sill samples. While nine housing units had only one window sill sample per house, 3 housing units had multiple window sill samples collected within a house. Altogether there were 18 window sill samples collected in 12 housing units (an average of 1.5 samples per unit). Failure rates of residential units were low based on floors or window troughs individually. Only 7% (11/151) of the residential units would have failed based on the results of floor samples and 3% (5/146) of the residential units would have failed based on the results of window trough samples. Among 12 housing units which had window sill samples, 5 housing units had at least one window sill dust-lead loading exceeding

the HUD Interim Guideline window sill standard, which resulted in a residential unit failure rate of 42% (5/12) based on the results of window sill samples.

G-2. Objective 2: Characterization of the Distribution of the Dust-Lead Loadings, Geometric Mean Dust-Lead Loadings, Variability Within a Housing Unit, and Variability Between Housing Units

Table G-2 presents geometric means and estimated variance components for lead loadings by component type. Dover data had a high window sill geometric mean, 462 $\mu g/ft^2$, and low floor and window trough clearance sample geometric means, 13.5 $\mu g/ft^2$ and 15.8 $\mu g/ft^2$, respectively. The interior renovation in Dover consisted of 1) removing lead painted radiators generally located under a window, and 2) window replacement. Window replacement did not necessarily include replacing the window sill. Among 12 housing units which had window sill samples, 4 housing units with 5 window sills had dust-lead loading results over 1,100 $\mu g/ft^2$. The fact that floor and window trough dust-lead loadings for those 4 housing units were all below HUD Interim Guideline standards suggests that window sills might have failed to be cleaned after renovation.

Figures G-1 and G-2 contain box and whisker plots that present the distribution of dust-lead loadings from the first and passed clearance visits by component type. Figures G-3 to G-5 contain box and whisker plots that present the distribution of dust-lead loadings from the first visit for floor, window sill, and window trough, respectively; Figures G-6 to G-8 contain box and whisker plots that present the distribution of dust-lead loadings from the passed clearance visits.

G-3. Objective 3: Characterization of the Correlation Between Components Sampled in the Same Work Area

The relationships among floor, window sill, and window trough wipe samples are another important aspect of examining a clearance testing program. One method of assessing the relationships among individual floor, window sill, and window trough wipe samples collected from the same room is to estimate linear correlation coefficients. Table G-3 displays the Pearson product-moment correlation coefficients and the associated sample size for the log lead loading measurements of individual floor, window sill, and window trough samples taken within the same room. The data shows that floor samples are positively correlated with both window sill

Table G-2. Clearance Testing Geometric Mean and Variance Component Estimates by Component Type for the Dover Housing Authority Data Set.

Site Visit	Component Tested	# of Samples	# of Rooms Sampled	# of Houses Sampled	Geometric Mean ($\mu g/ft^2$)	$\sigma_{Between}$ ln ($\mu g/ft^2$)	σ_{Within} ln ($\mu g/ft^2$)	95% Confidence Interval on Geometric Mean ($\mu g/ft^2$)	
								Lower Bound	Upper Bound
First	Floor	633	623	151	13.5	0.74	1.02	11.7	15.6
	Sill	18	18	12	462	.	1.15	255	837
	Trough	265	261	146	15.8	0.63	1.26	13.1	19.0

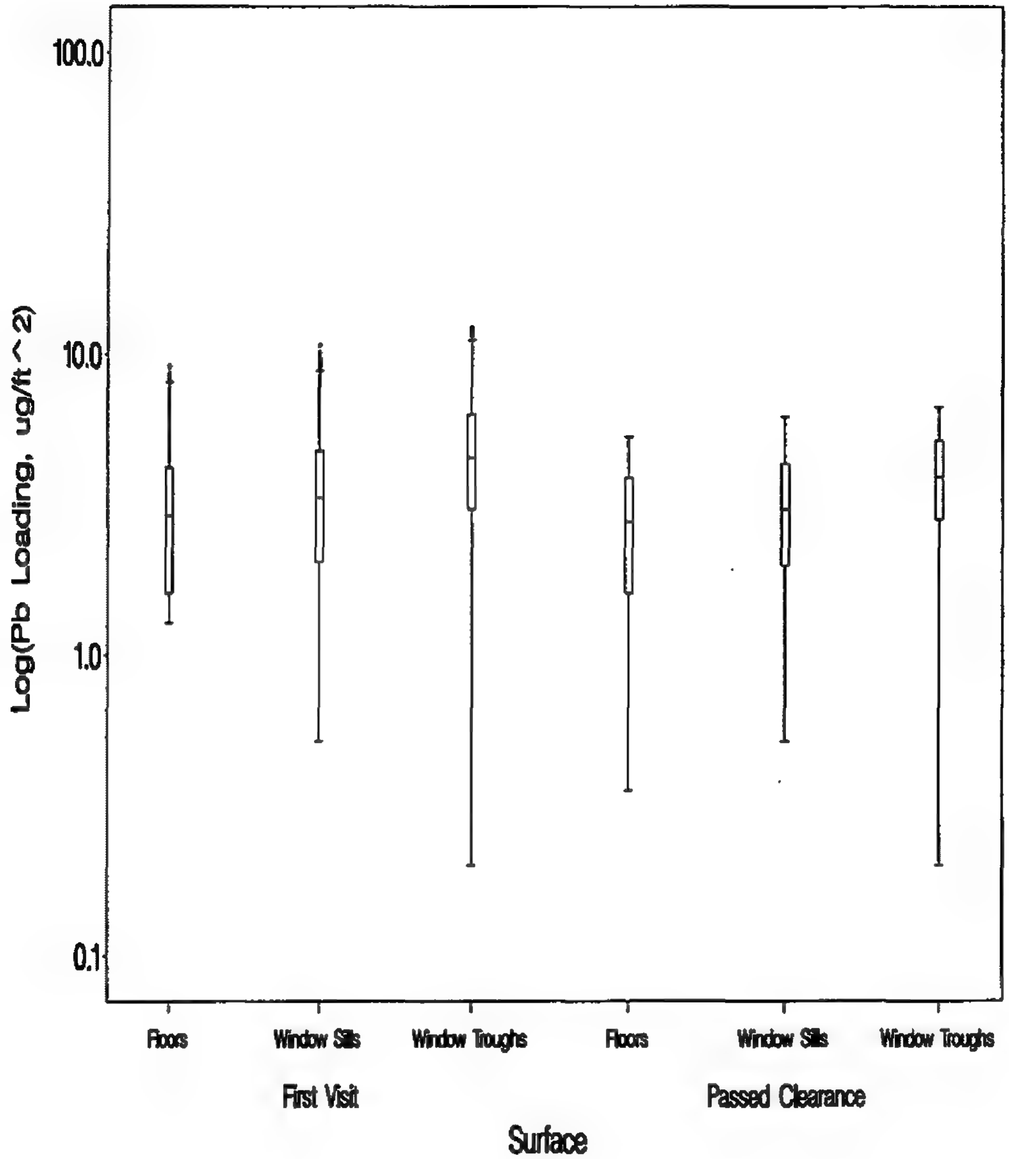

Figure G-1. **Comparison of ln-Transformed Dust-Lead Loadings from the First Site Visit vs. Passed Clearance Results on an Expanded Scale.**

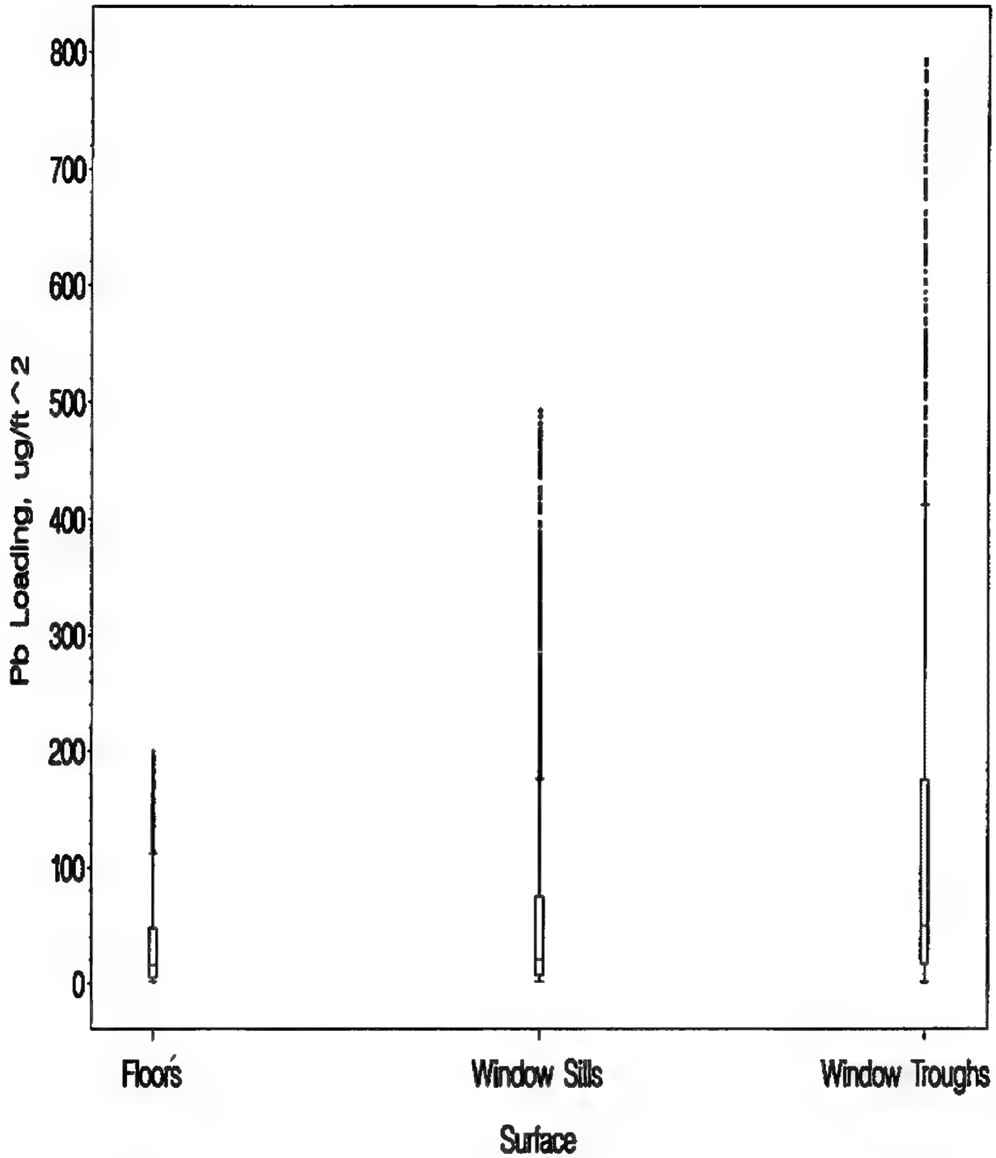

Figure G-2. Box and Whisker Plots of the Distribution of Dust-Lead Loadings from the Passed Clearance Data.

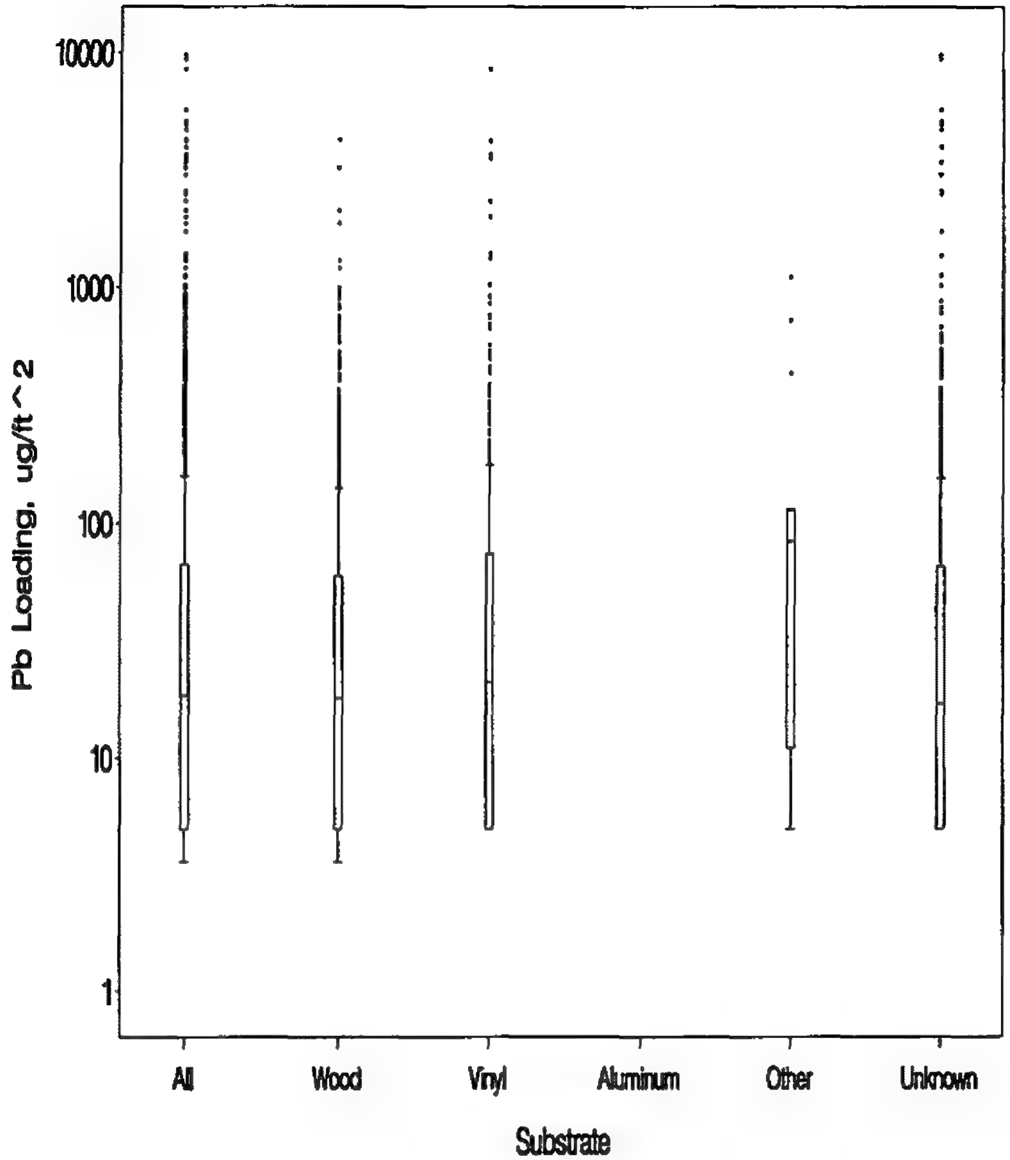

Figure G-3. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the First Site Visit.

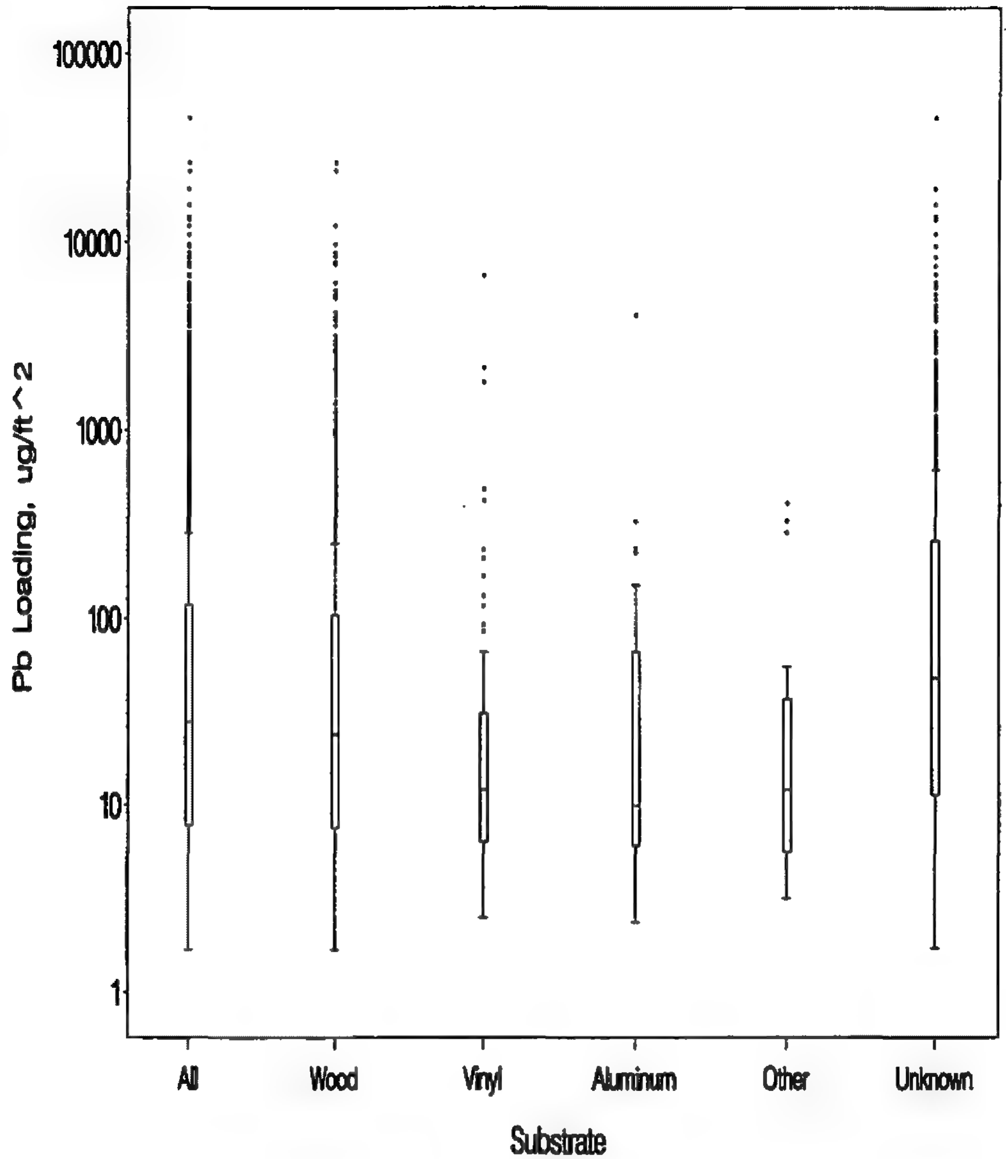

Figure G-4. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the First Site Visit.

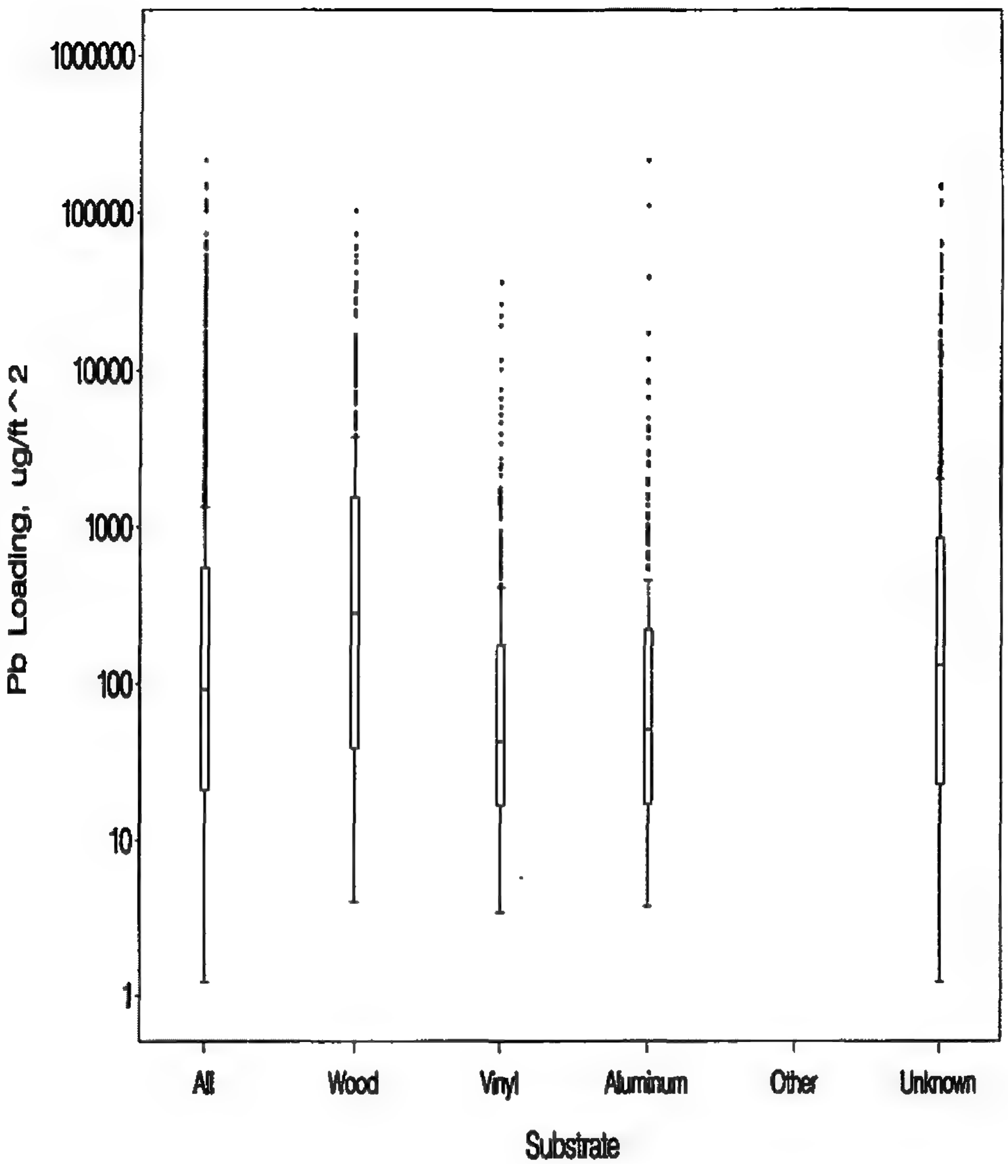

Figure G-5. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the First Site Visit.

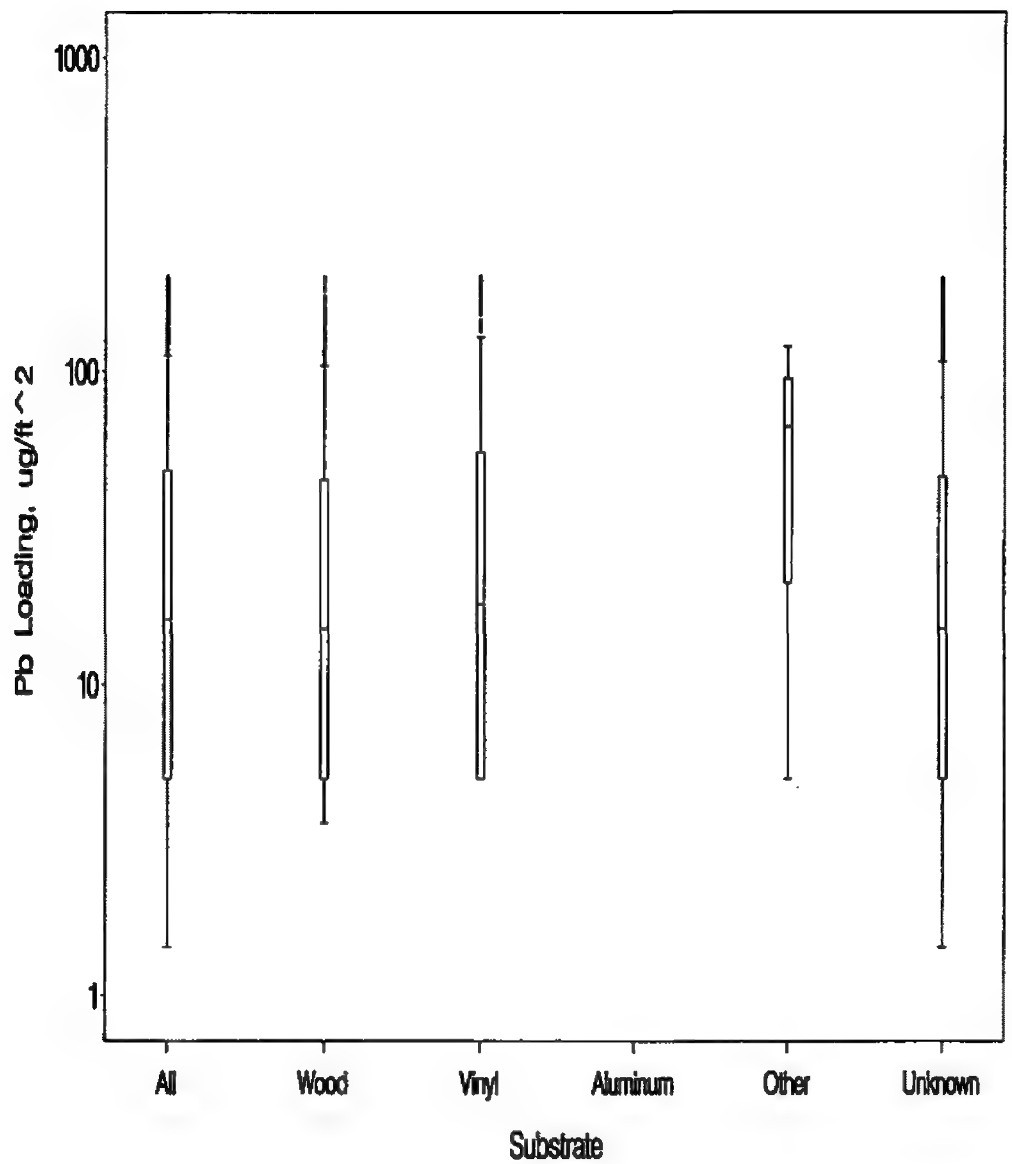

Figure G-6. Box and Whisker Plots of the Distribution of Floor Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

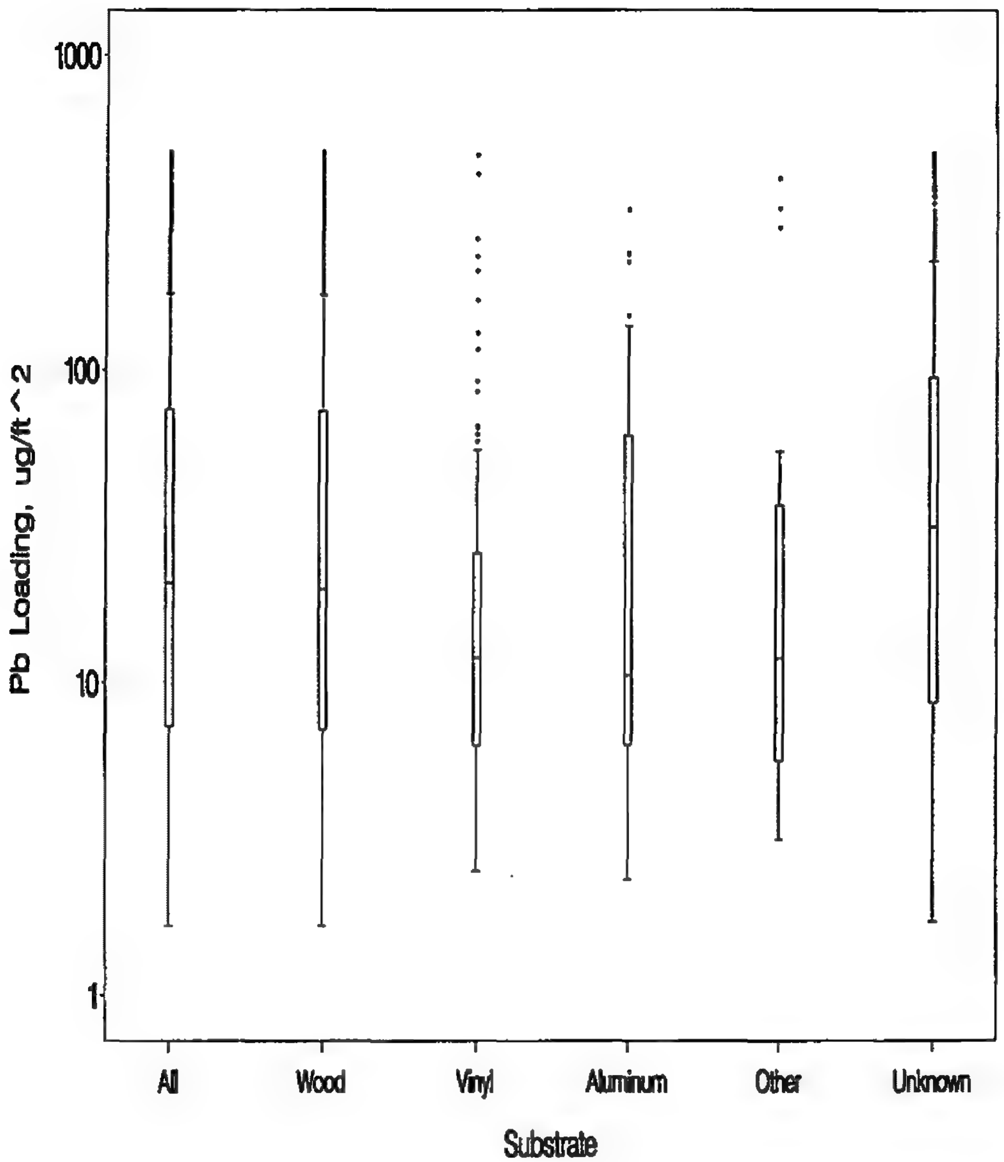

Figure G-7. Box and Whisker Plots of the Distribution of Window Sill Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

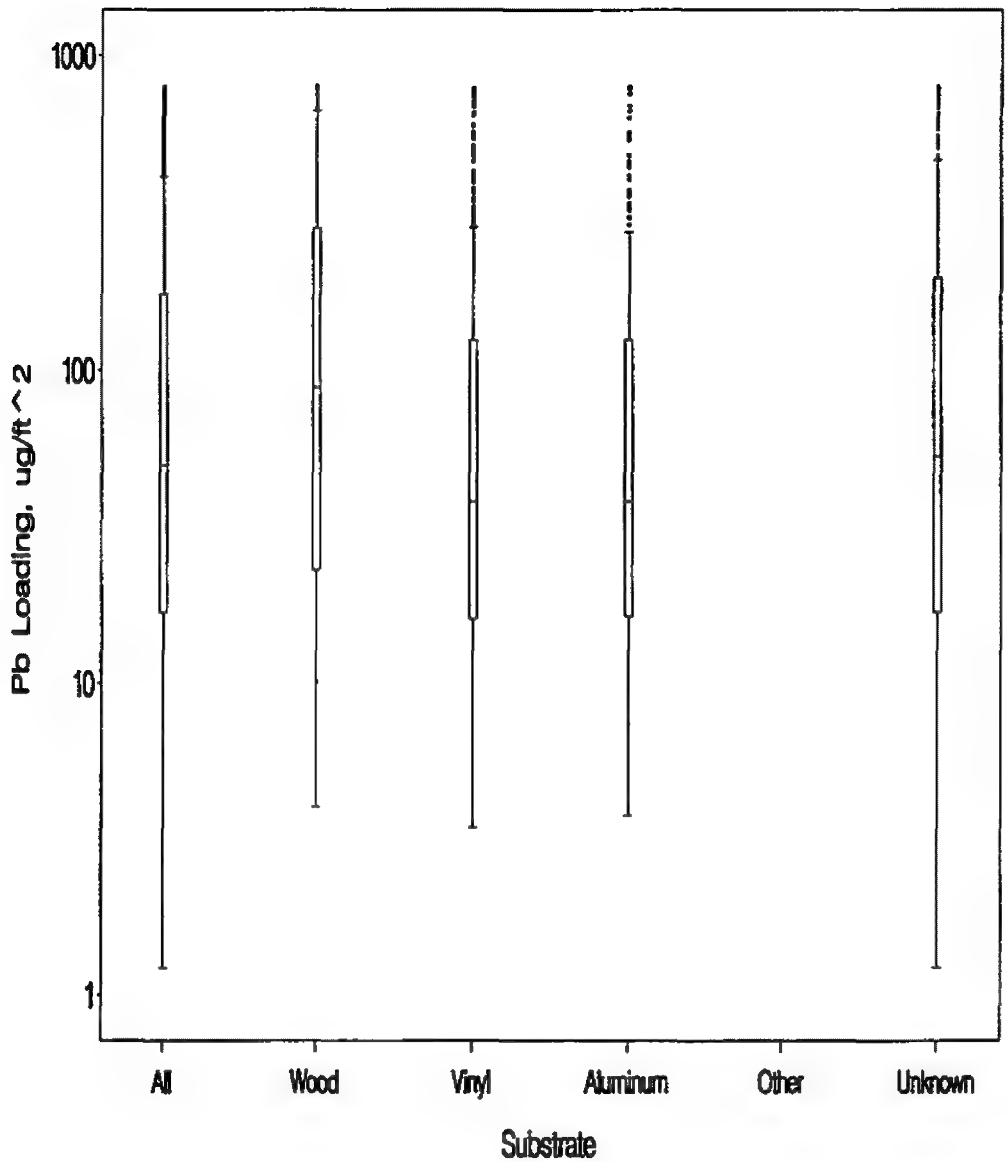

Figure G-8. Box and Whisker Plots of the Distribution of Window Trough Dust-Lead Loadings by Substrate for the Passed Clearance Visits.

Table G-3. Observed Within-Room Correlation Coefficients Between Pb Loading Measurements Collected From Floors, Window Sills and Troughs for the Dover Housing Authority Data.

Site Visit	City	Observed Within-Room Correlation Coefficients Between			
		Floors and Window Sills		Floors and Window Troughs	
		$\rho_{Floors,Sills}$	n	$\rho_{Floors,Troughs}$	n
First	Dover	0.16	13	0.12	184

and window trough samples. The correlations between floor and window trough results and between floor and window sill results were not significant at the 0.05 level. A lack of data prevented a correlation between window sills and window troughs from being estimated.

The conditional probabilities of a sample passing or failing a standard are given in Table G-4. These analyses were conducted on two different sets of data, the first set using all possible paired observations from within the same room. The second subset of data restricted the analyses to rooms in which floor, window sill, and window trough lead loadings were simultaneously observed. Note that the conditional probabilities results between window sills and floors or window troughs may not be reliable due to lack of data.

For both types of estimates and both data sets included in the analysis, between floors and window sills and between floors and window troughs, the probability that one component passes clearance given that another component passes clearance ranges from 60% to 100%, while the probability that one component fails clearance testing given that another component in the same room fails clearance testing ranges from 0% to 54%.

G-4. Objective 4: Demonstration of the Impact of Composite Sampling on Pass/Fail Rates of Houses

Individual sample lead loading results from each component type within a residential unit were combined to construct simulated composite sample results.

Table G-5 provides the number of residential units which were investigated by the number of individual samples collected from each component type. For example, there were 17 residential units where five floor dust-wipe samples were taken. In this analysis, residential units containing more than four samples from a component type resulted in the estimation of multiple

Table G-4. Conditional Probabilities for Clearance Testing Estimated Using 2 x 2 Contingency Tables and Normal Probability Theory Based on the First Site Visit

Conditional Probability	Contingency Table Estimates		Normal Theory Estimates		Conditional Probability	Contingency Table Estimates		Normal Theory Estimates	
	All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room		All Possible Pairs	F, S, and T within the same room	All Possible Pairs	F, S, and T within the same room
$P(F<200 \mid S<500)$	1.000	1.000	0.955	.	$P(F \geq 200 \mid S \geq 500)$	0.000	.	0.075	.
$P(S<500 \mid F<200)$	0.692	1.000	0.599	.	$P(S \geq 500 \mid F \geq 200)$	.	.	0.535	.
$P(F<200 \mid T<800)$	0.983	1.000	0.988	.	$P(F \geq 200 \mid T \geq 800)$	0.000	.	0.028	.
$P(T<800 \mid F<200)$	0.977	1.000	0.997	.	$P(T \geq 800 \mid F \geq 200)$	0.000	.	0.006	.
$P(S<500 \mid T<800)$	0.500	1.000	0.339	.	$P(S \geq 500 \mid T \geq 800)$	.	.	1.000	.
$P(T<800 \mid S<500)$	1.000	1.000	1.000	.	$P(T \geq 800 \mid S \geq 500)$	0.000	.	0.297	.
$P(F<200 \mid S<500,T<800)$	.	1.000	.	.	$P(F \geq 200 \mid S \geq 500,T \geq 800)$	.	.	.	.
$P(S<500 \mid F<200,T<800)$	.	1.000	.	.	$P(S \geq 500 \mid F \geq 200,T \geq 800)$	.	.	.	.
$P(T<800 \mid F<200,S<500)$	.	1.000	.	.	$P(T \geq 800 \mid F \geq 200,S \geq 500)$	.	.	.	.

simulated composite sample results. Therefore, summing all the units that had five or more individual samples, approximately 19% (29/151) of the residential units resulted in the

Table G-5. Number of Residential Units that Contained (N) Individual Samples of Each Component Type Based on First Site Visit Clearance Testing Data From the Dover Housing Authority.

(N) Number of Individual Samples	Component Type		
	Floors	Window Sills	Window Troughs
1	3	9	32
2	2	1	110
3	6	1	3
4	111	1	1
5	17	0	0
6	8	0	0
7	1	0	0
8	3	0	0
Total	151	12	146
Total with N≥5	29	0	0

estimation of multiple simulated composite samples from floors. None of the residential units tested resulted in the estimation of multiple simulated composite samples from window sills or window troughs. This occurred since all of the units investigated had four or less individual samples taken from window sills and four or less samples taken from window troughs. When there were four or fewer individual samples from a component type within a housing unit, the simulated composite sample included all samples.

For each component type within a residential unit, the set of individual clearance sample lead loading results were used to construct simulated composite samples for the purpose of evaluating the three composite sample clearance criteria (Standard, Standard/n, and 2×Standard/n). For each combination of component type and composite clearance criterion, each residential unit either passed clearance, failed clearance, or yielded inconclusive results based on the simulated composite samples. Inconclusive results were only possible for those residential units which contained multiple simulated composite samples. Uncertainty in the decision rule is

created by the multitude of ways in which multiple composite samples can be formed within residential units which contained five or more individual clearance samples. Some of the possible multiple composite samples formed may pass while other possible composite samples may fail. As seen in Table G-6, the incidence of this type of uncertainty was very low for this data set compared to the other data sets. The maximum observed percentage of residential units with greater than four individual clearance samples of a given component type that resulted in inconclusive results was 2.0% for floor samples using the Standard Rule.

Table G-6. Individual Sample Clearance Results Versus Simulated Composite Clearance Results Based on Data from the Dover Housing Authority.

Composite Clearance Criteria	Composite Sample Clearance Result	Individual Sample Clearance Results					
		Floors		Window Sills		Window Troughs	
		Pass	Fail	Pass	Fail	Pass	Fail
Standard	Pass	140	5	7	0	141	2
	Inconclusive	0	3	0	0	0	0
	Fail	0	3	0	5	0	3
Standard/n	Pass	124	0	7	0	141	0
	Inconclusive	2	0	0	0	0	0
	Fail	14	11	0	5	0	5
2 × Standard/n	Pass	138	1	7	0	141	0
	Inconclusive	0	1	0	0	0	0
	Fail	2	9	0	5	0	5

The performance characteristics of each combination of component type and composite clearance criteria are presented in Table G-7 in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). By design, the Standard/n Rule sacrifices specificity for sensitivity. The sensitivity for the Standard/n Rule is always 1.00 while the specificity for this rule is estimated to be 0.89 for floors, 1.00 for window sills, and 1.00 for window troughs. On the other hand, the Standard Rule sacrifices sensitivity for specificity. The specificity for the Standard Rule is always 1.00 while the sensitivity for this rule is estimated to be 0.27 for floors, 1.00 for window sills, and 1.00 for window troughs. The 2×Standard/n Rule attempts to maximize both sensitivity and specificity. The values of sensitivity for the 2×Standard/n Rule are always at least as high as those calculated for the Standard Rule. For floors, the 2×Standard/n Rule, with an estimated sensitivity of 0.82, seems to do quite a bit better than the Standard Rule. Similarly, the values of specificity are at least as high as those calculated

for the Standard/n Rule. Estimates of sensitivity and specificity in these examples are always conservative, because inconclusive composite test results (i.e., houses in which only a fraction of the simulated composite samples passed or failed) are included in the denominator for each estimate, but are never included in the numerator.

Table G-7. Performance Characteristics of Composite Clearance Criteria Based on Data from the Dover Housing Authority.

Component Type	Performance Characteristic	Composite Clearance Criteria		
		Standard	Standard/n	2 × Standard/n
Floors	Sensitivity	0.27	1.00	0.82
	Specificity	1.00	0.89	0.99
	PPV	1.00	0.44	0.82
	NPV	0.97	1.00	0.99
Window Sills	Sensitivity	1.00	1.00	1.00
	Specificity	1.00	1.00	1.00
	PPV	1.00	1.00	1.00
	NPV	1.00	1.00	1.00
Window Troughs	Sensitivity	0.60	1.00	1.00
	Specificity	1.00	1.00	1.00
	PPV	1.00	1.00	1.00
	NPV	0.99	1.00	1.00

Table G-7 shows that each of the three composite clearance testing criteria can have different specificity and sensitivity rates. These rates correspond to the consistency between clearance decisions based on individual clearance samples and clearance decisions based on simulated composite samples. To further characterize the performance of each of the three composite clearance criterion, the following logistic regression model was fitted for each combination of component type and composite clearance criteria to describe the relationship between the probability of passing clearance and the maximum lead loading present in all of the sampling locations tested in a residential unit:

$$\text{Logit}(\pi_{ijk}) = \beta_0 + \beta_1 * \text{Max}_{ij}$$

where π_{ijk} is the estimated probability of clearance for component(j) in house(i) under composite criterion (k), and Max_{ij} is the maximum individual sample lead loading result in house(i) for component(j).

The estimated relationship between the probability of passing clearance based on simulated composite samples and the maximum lead loading in individual floor samples is presented graphically in Figure G-9. In this figure, the solid, long-dashed, and finely-dashed lines represent the estimated relationship for the Standard, Standard/n, and 2×Standard/n Rules, respectively. These same relationships for window sills and window troughs were inestimable because of the nature of the data. Essentially, an infinite number of curves could be fit to estimate the relationship, but there is no criterion for choosing the optimal one.

Table G-8 provides parameter estimates and associated standard errors from the logistic regression models, as well as estimates of the probability of passing clearance (using composite samples) when the maximum lead loading among all locations included in the composite sampling scheme is greater than or equal to ½, 1, 2, and 4 times the associated interim HUD standard for individual samples. The estimates for the probability of passing based on composite samples formed from window sill samples or window trough samples do not appear in the table because the related parameters are not estimable due to the reasons stated in the previous paragraph. The low sensitivity of the Standard Rule is demonstrated by the high estimated probability (0.83) of passing when the maximum individual floor sample lead loading is equal to the 2 times the HUD Standard. The estimated relationship for the Standard/n Rule demonstrates this rule's high sensitivity (probability of passing is very low when the maximum individual sample lead loading is greater than or equal to the HUD Standard) along with the loss in specificity for this rule (probability of passing is only 0.73 when the maximum individual sample lead loading is equal to ½ HUD Standard). Once again, the 2×Standard/n Rule is shown to be a compromise between the Standard and Standard/n Rules. At ½ HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is 0.99, and at 2×HUD Standard, the estimated probability of passing clearance testing under the 2×Standard/n Rule is 0.00.

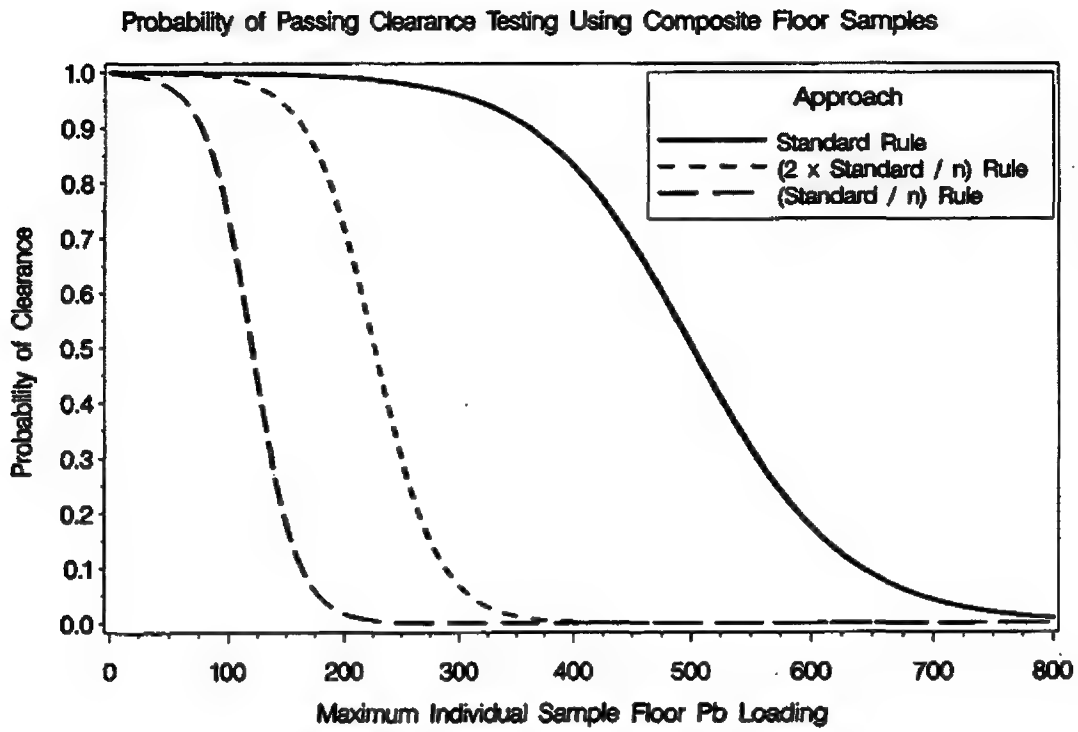

Figure G-9. Estimated Relationship Between the Probability of a Residential Unit Passing Clearance Testing versus the Maximum Individual Lead-Loading Result by Component Type Based on Simulated Composite Samples from the Dover Housing Authority.

Table G-8. Results from a Logistic Regression Model which Investigates the Relationship between the Probability of Clearance and the Maximum Individual Sample Lead Loading, Under Three Different Composite Sampling Decision Rules, Using Data from the Dover Housing Authority.

Component Tested	Decision Rule	Number of Houses with Simulated Composite Clearance Status of			Estimated Intercept		Estimated Slope		Probability of Clearance When the Maximum Individual Sample Result Within a House Is Equal to			
		Pass	Inconclusive	Fail	β_0	s.e.(β_0)	β_1	s.e.(β_1)	1/2 HUD Standard	HUD Standard	2*HUD Standard	4*HUD Standard
Floor	Standard	145	3	3	7.874	2.605	-0.016	0.006	1.00	0.99	0.83	0.01
	2 × Standard/n	139	1	11	7.995	2.075	-0.035	0.011	0.99	0.71	0.00	0.00
	Standard/n	124	2	25	6.084	1.070	-0.051	0.011	0.73	0.02	0.00	0.00
Window Sills	Standard	7	0	5	.	.	.	.	.	.	.	.
	2 × Standard/n	7	0	5	.	.	.	.	.	.	.	.
	Standard/n	7	0	5	.	.	.	.	.	.	.	.
Window Troughs	Standard	143	0	3	.	.	.	.	.	.	.	.
	2 × Standard/n	141	0	5	.	.	.	.	.	.	.	.
	Standard/n	141	0	5	.	.	.	.	.	.	.	.

APPENDIX H

Additional Analysis Results on the Percentage of Housing Units That Passed Clearance on the First Site Visit, by the Number of Individual Samples Collected Within a Housing Unit

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Additional Analysis Results on the Percentage of Housing Units That Passed Clearance on the First Site Visit, by the Number of Individual Samples Collected Within a Housing Unit

Appendix H presents additional analysis results on the percentage of housing units that passed clearance on the first site visit, by the number of individual samples collected within a housing unit. Clearance standards used in this appendix were based on HUD Interim Guidelines (200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window troughs). Table H-1 uses a format similar to that of Table 6-13 in the text, but Table H-1 presents the percentage of units that passed clearance on the first site visit for the applicable component in each part of the table (floor, window sill, and window trough).

Tables H-2a, H-3a, and H-4a present the number of residential units that contained individual samples for the first site visit clearance testing data from the HUD Grantee Program (both High and Low data groups), by interior intervention strategy code, for floors, window sills, and window troughs, respectively. Tables H-2b, H-3b, and H-4b, companion tables for Tables H-2a, H-3a, and H-4a, present the percentage of residential units that passed clearance for the first site visit clearance testing data from the HUD Grantee Program (both High and Low data groups), by interior intervention strategy code, for floors, window sills, and window troughs, respectively. HUD Grantees reported the intensity of the interior intervention as a strategy code (level 01 to 07). Higher strategy levels reflect more intensive treatment. Each dwelling unit was assigned only one interior intervention strategy. The interior intervention strategies were summarized in Table 4-1.

Table H-2a, H-3a, and H-4a show that, regardless of component type, level 05 of the interior intervention strategy was used in housing units more than any other intervention strategy for both HUD Grantee High and Low data groups. Level 05 of the interior intervention strategy includes window replacement and wall enclosure/encapsulation, and other lower levels of intervention activities.

Tables H-2b, H-3b, and H-4b show that, generally, the percentage of housing units passing clearance does not increase as the intensity of the interior intervention increases. This is

true across all 3 components and for both HUD Grantee High and Low data groups. The most popular interior intervention strategy, level 05, has residential unit passing rates of 86%, 95%, and 94% based on floors, window sills, and window troughs, respectively, for the HUD Grantee High data group. For the HUD Grantee Low data group, interior intervention strategy level 05 has residential unit passing rates of 83%, 91%, and 91% based on floors, window sills, and window troughs, respectively.

Table H-1. Percentage of Housing Units that Passed Clearance for Each Data Source That Contained (N) Individual Clearance Samples of Each Component Type Based on the First Site Visit.

Data Source	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	All
Floor Standard 200 $\mu g/ft^2$										
Maryland	89	87	80	81	73	70	67	74	64	79
HUD FHA	50	71	33	63	58	53	47	65	41	54
HUD PHA	100	92	75	69	71	63	76	38	80	74
HUD Grantee (High)*	87	86	89	86	82	85	79	81	60	85
HUD Grantee (Low)**	93	92	82	92	90	78	57	50	67	89
Atlantic City	100	86	70	85	70	80	100	50	100	80
Cleveland	.	100	62	50	60	100	.	.	100	63
Dover	67	100	83	96	82	88	100	67	.	93
Window Sill Standard 500 $\mu g/ft^2$										
Maryland	79	79	74	73	88	80	71	78	69	77
HUD FHA	88	60	71	88	57	70	55	33	57	63
HUD PHA	100	93	87	96	86	96	.	100	.	93
HUD Grantee (High)*	90	94	89	88	90	65	100	100	0	91
HUD Grantee (Low)**	94	95	91	73	75	50	.	.	0	93
Atlantic City	100	89	67	50	100	.	.	.	.	80
Cleveland	100	100	92	100	100	.	.	.	.	97
Dover	78	0	0	0	.	.	.	.	.	58
Window Trough Standard 800 $\mu g/ft^2$										
Maryland	72	65	62	65	63	68	36	46	47	63
HUD FHA	92	50	26	38	50	21	50	0	0	44
HUD PHA	100	87	100	100	91	100	.	100	.	95
HUD Grantee (High)*	92	89	94	96	92	71	100	100	.	91
HUD Grantee (Low)**	91	86	85	62	67	.	.	.	.	88
Atlantic City	100	95	100	83	100	.	.	.	.	96
Cleveland	93	83	100	100	.	.	.	.	.	92
Dover	94	97	100	100	.	.	.	.	.	97

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table H-2a. Number of Residential Units that Contained (N) Individual Floor Samples for the First Site Visit Clearance Testing Data from the HUD Grantee Program, by Interior Intervention Strategy Code.

Interior Intervention Strategy Code	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
HUD Grantee (High)*										
01	14	10	7	4	2	2	0	0	0	39
02	30	70	28	24	15	9	1	0	0	177
03	24	31	15	9	7	5	4	0	0	95
04	29	80	64	61	45	38	11	19	18	365
05	83	113	123	128	108	161	93	14	21	844
06	1	0	1	2	5	4	2	0	0	15
07	0	2	2	1	0	0	0	0	0	5
Missing	55	107	94	114	76	69	31	3	3	552
Total	236	413	334	343	258	288	142	36	42	2092
HUD Grantee (Low)**										
01	2	4	1	1	0	0	0	0	0	8
02	21	5	4	10	4	2	0	0	0	46
03	15	21	33	40	44	15	1	1	0	170
04	9	15	19	19	9	6	2	0	0	79
05	40	34	48	59	53	8	3	0	1	246
06	0	4	10	47	15	1	0	0	1	78
07	0	0	1	0	0	0	0	0	0	1
Missing	42	41	43	170	76	18	1	1	1	393
Total	129	124	159	346	201	50	7	2	3	1021

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table H-2b. Percentage of Residential Units that Passed Clearance for Floors (Based on Standard at 200 $\mu g/ft^2$) for the First Site Visit Clearance Testing Data from the HUD Grantee Program, by Interior Intervention Strategy Code.

Interior Intervention Strategy Code	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
HUD Grantee (High)*										
01	93	90	71	100	50	100	.	.	.	87
02	87	89	86	88	87	89	100	.	.	88
03	83	65	80	78	43	100	75	.	.	74
04	72	88	94	82	84	82	73	84	50	83
05	89	86	89	85	89	86	80	71	67	86
06	0	.	100	100	60	75	100	.	.	73
07	.	100	100	0	.	.	.	.	.	80
Missing	93	90	89	89	76	81	77	100	67	86
Total	87	86	89	86	82	85	79	81	60	85
HUD Grantee (Low)**										
01	50	100	100	100	.	.	.	.	.	88
02	100	80	100	80	75	50	.	.	.	89
03	87	90	94	93	91	93	0	0	.	91
04	89	87	74	74	78	67	50	.	.	77
05	95	91	77	81	81	63	100	.	0	83
06	.	100	60	96	93	100	.	.	100	91
07	.	.	100	.	.	.	.	.	.	100
Missing	93	95	86	97	96	78	0	100	100	94
Total	93	92	82	92	90	78	57	50	67	89

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table H-3a. Number of Residential Units that Contained (N) Individual Window Sill Samples for the First Site Visit Clearance Testing Data from the HUD Grantee Program, by Interior Intervention Strategy Code.

Interior Intervention Strategy Code	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
HUD Grantee (High)*										
01	9	10	11	3	0	0	0	1	0	34
02	36	76	37	13	3	0	0	0	0	165
03	24	22	20	7	2	0	0	0	0	75
04	61	123	107	51	10	8	1	0	0	361
05	80	520	155	42	24	9	1	0	1	832
06	1	8	3	2	0	0	0	0	0	14
07	0	1	3	1	0	0	0	0	0	5
Missing	52	308	165	14	2	3	0	1	0	545
Total	263	1068	501	133	41	20	2	2	1	2031
HUD Grantee (Low)**										
01	2	2	2	0	0	0	0	0	0	6
02	13	28	3	0	0	0	0	0	0	44
03	11	128	20	3	1	0	0	0	0	163
04	7	31	30	7	1	0	0	0	0	76
05	30	108	80	15	0	1	0	0	1	235
06	9	49	9	0	0	0	0	0	0	67
07	0	1	0	0	0	0	0	0	0	1
Missing	48	240	70	15	2	1	0	0	0	376
Total	120	587	214	40	4	2	0	0	1	968

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.

** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table H-3b. Percentage of Residential Units that Passed Clearance for Window Sills (Based on Standard at 500 $\mu g/ft^2$) for the First Site Visit Clearance Testing Data from the HUD Grantee Program, by Interior Intervention Strategy Code.

Interior Intervention Strategy Code	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
HUD Grantee (High)*										
01	67	90	100	100	.	.	.	100	.	88
02	78	80	73	85	33	.	.	.	.	78
03	96	86	90	86	100	.	.	.	.	91
04	87	93	94	86	90	38	100	.	.	90
05	93	97	93	90	96	78	100	.	.	95
06	100	88	100	100	.	.	.	.	.	93
07	.	100	100	100	.	.	.	.	.	100
Missing	98	93	85	86	100	100	.	100	.	91
Total	90	94	89	88	90	65	100	100	.	91
HUD Grantee (Low)**										
01	50	100	100	.	.	.	.	.	.	83
02	100	96	33	.	.	.	.	.	.	93
03	91	95	95	67	0	.	.	.	.	94
04	86	87	80	29	100	.	.	.	.	79
05	97	93	90	80	.	0	.	.	.	91
06	89	98	100	.	.	.	.	.	.	97
07	.	100	.	.	.	.	.	.	.	100
Missing	96	95	97	87	100	100	.	.	.	95
Total	94	95	91	73	75	50	.	.	.	93

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table H-4a. Number of Residential Units that Contained (N) Individual Window Trough Samples for the First Site Visit Clearance Testing Data from the HUD Grantee Program, by Interior Intervention Strategy Code.

Interior Intervention Strategy Code	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
HUD Grantee (High)*										
01	11	4	0	0	0	0	0	0	0	15
02	99	17	1	0	0	0	0	0	0	117
03	24	14	1	0	0	0	0	0	0	39
04	87	109	57	21	4	5	0	1	0	284
05	260	350	78	21	9	2	1	0	0	721
06	0	12	2	0	0	0	0	0	0	14
07	5	0	0	0	0	0	0	0	0	5
Missing	246	221	31	4	0	0	0	0	0	502
Total	732	727	170	46	13	7	1	1	0	1697
HUD Grantee (Low)**										
01	4	2	0	0	0	0	0	0	0	6
02	13	27	2	0	0	0	0	0	0	42
03	59	72	21	0	1	0	0	0	0	153
04	32	27	10	4	0	0	0	0	0	73
05	148	52	9	3	2	0	0	0	0	214
06	51	14	0	1	0	0	0	0	0	66
07	1	0	0	0	0	0	0	0	0	1
Missing	187	108	18	5	0	0	0	0	0	318
Total	495	302	60	13	3	0	0	0	0	873

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

Table H-4b. Percentage of Residential Units that Passed Clearance for Window Troughs (Based on Standard at 800 $\mu g/ft^2$) for the First Site Visit Clearance Testing Data from the HUD Grantee Program, by Interior Intervention Strategy Code.

Interior Intervention Strategy Code	Number of Individual Samples									
	1	2	3	4	5	6	7	8	9+	Total
HUD Grantee (High)*										
01	100	75	.	.	.	.	.	.	.	93
02	88	94	100	.	.	.	.	.	.	89
03	96	93	100	.	.	.	.	.	.	95
04	95	93	91	100	100	60	.	100	.	93
05	96	91	96	95	89	100	100	.	.	94
06	.	92	50	.	.	.	.	.	.	86
07	100	.	.	.	.	.	.	.	.	100
Missing	88	84	97	75	.	.	.	.	.	86
Total	92	89	94	96	92	71	100	100	.	91
HUD Grantee (Low)**										
01	75	100	.	.	.	.	.	.	.	83
02	77	59	50	.	.	.	.	.	.	64
03	93	93	86	.	0	.	.	.	.	92
04	88	70	100	100	.	.	.	.	.	84
05	94	85	89	67	100	.	.	.	.	91
06	88	86	.	100	.	.	.	.	.	88
07	100	.	.	.	.	.	.	.	.	100
Missing	91	92	78	20	.	.	.	.	.	90
Total	91	86	85	62	67	.	.	.	.	88

* Grantees that used 200 $\mu g/ft^2$ as clearance standard for floor.
** Grantees that used 100 $\mu g/ft^2$ or 80 $\mu g/ft^2$ as clearance standard for floor.

APPENDIX I

Additional Analysis Results

APPENDIX I

ADDITIONAL ANALYSIS RESULTS

Appendix I presents additional analysis results on the distributions of the clearance data. Figures I-1 to I-6 display box and whisker plots for the distributions of floor, window sill, and window well dust-lead loadings (µg/ft^2) and log-transformed dust-lead loadings (log µg/ft^2) from the first site visit by substrates for Dover and Maryland data. Detailed values for different percentiles for the untransformed dust-lead loadings (µg/ft^2) are presented in Table I-1. Figures I-7, I-8, and I-9 display box and whisker plots for the distributions of dust-lead loadings (µg/ft^2) and log-transformed dust-lead loadings (log µg/ft^2) from the first site visit by data source, for floors, window sills, and window wells, respectively. Similar detailed values for different percentiles for the untransformed dust-lead loadings (µg/ft^2) are presented in Table I-2.

Box and whisker plots of the percentiles by surface and substrate for Dover and Maryland on the "Passed Clearance" data sets are provided in Figures I-10 through I-15. Specific upper tail percentiles are given in Table I-3. Figures I-16 through I-18 display the distribution of clearance results for data sources that "Passed Clearance." Additional percentile information for these data sources is presented in Table I-4.

In Tables I-2 and I-4, Figures I-7 to I-9, and Figures I-16 to I-18, "Grantee 1" refers to data from a group of nine grantees (Alameda County, Baltimore, Boston, California, Massachusetts, Milwaukee, Rhode Island, Vermont, and Wisconsin) in the HUD Grantee Program that used the HUD Interim Guidelines clearance standards, i.e., 200, 500, and 800 µg/ft^2 for floors, window sills, and window troughs, respectively; "Grantee 2" refers to data from the other group of five grantees (Cleveland, Chicago, New Jersey, New York City, and Minnesota) that used a lower floor dust-lead clearance standard (i.e., 100 µg/ft^2 or 80 µg/ft^2). These were referred as "HUD Grantee (High)" and "HUD Grantee (Low)" in the main body of the report.

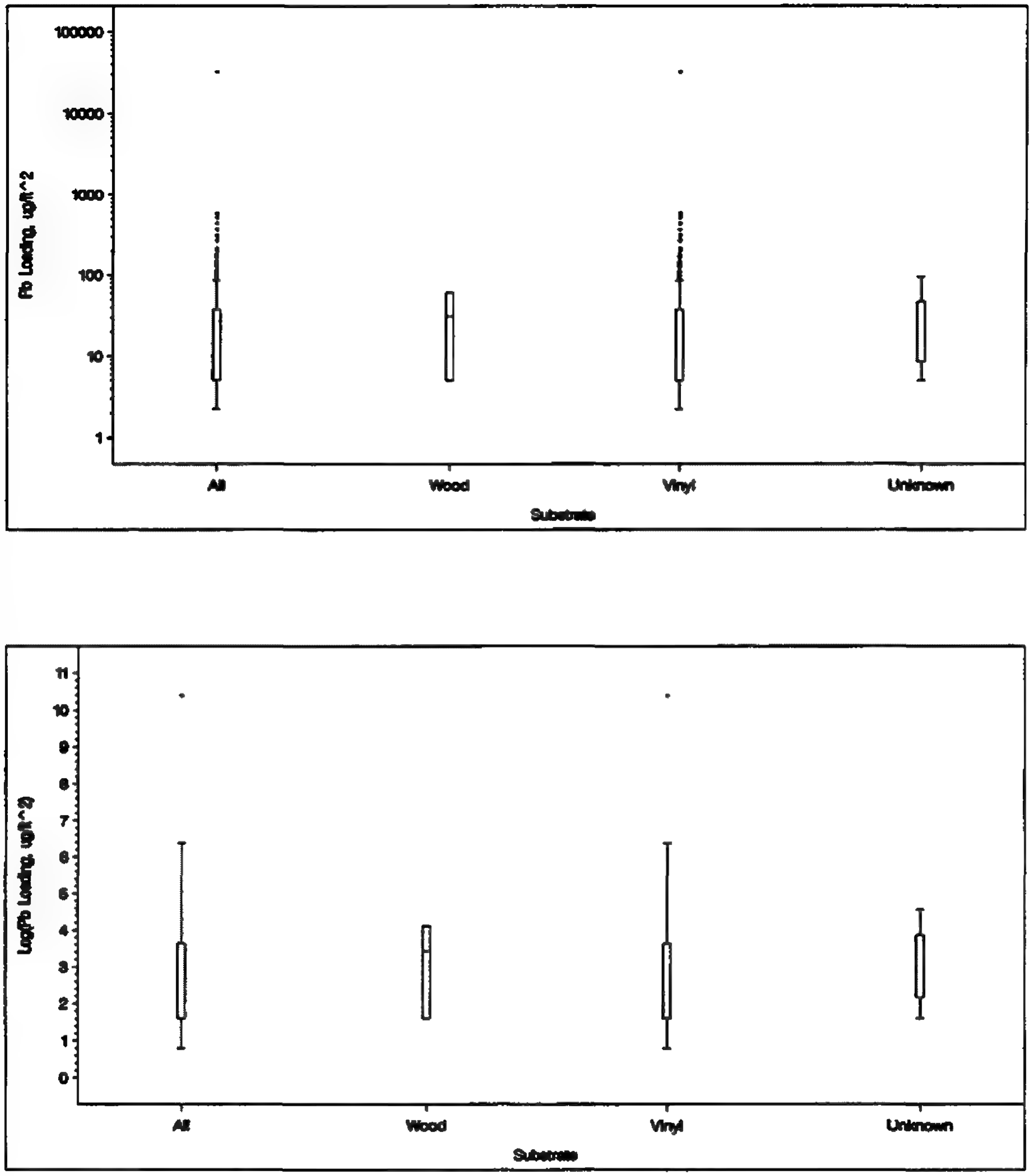
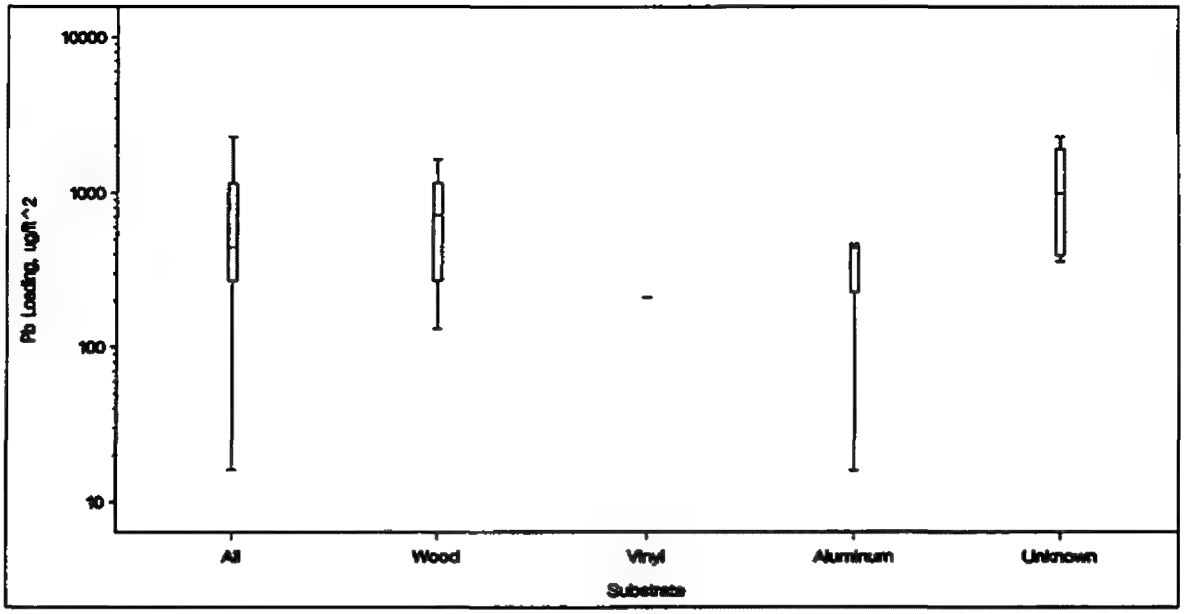


Figure I-1. **Box and Whisker Plots of the Distributions of Floors Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Dover Data by Substrate for the First Site Visit**



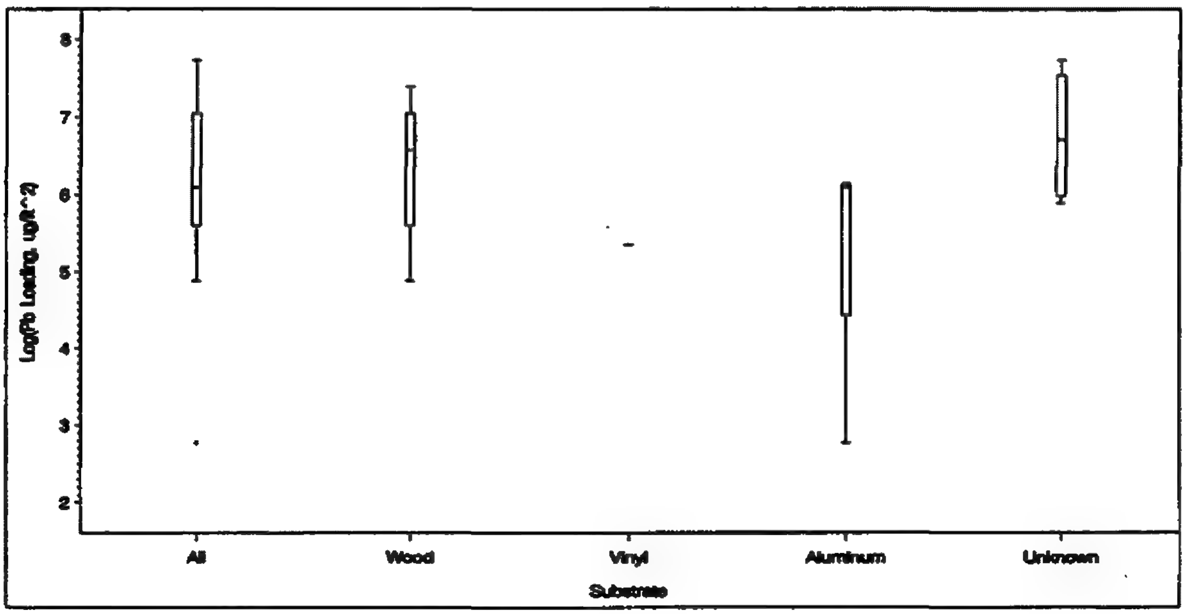


Figure I-2. **Box and Whisker Plots of the Distributions of Window Sills Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Dover Data by Substrate for the First Site Visit**

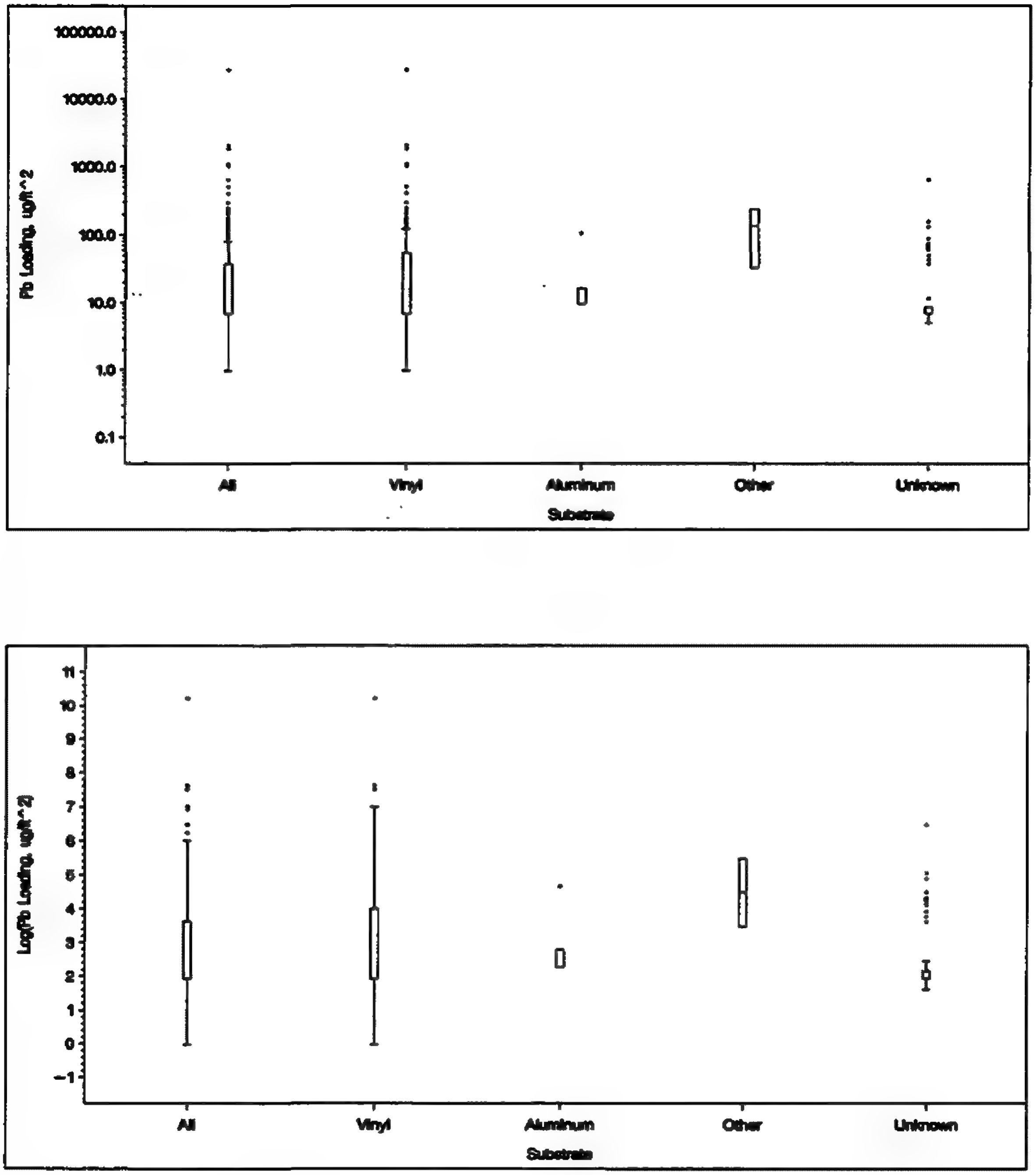


Figure I-3. Box and Whisker Plots of the Distributions of Window Troughs Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Dover Data by Substrate for the First Site Visit

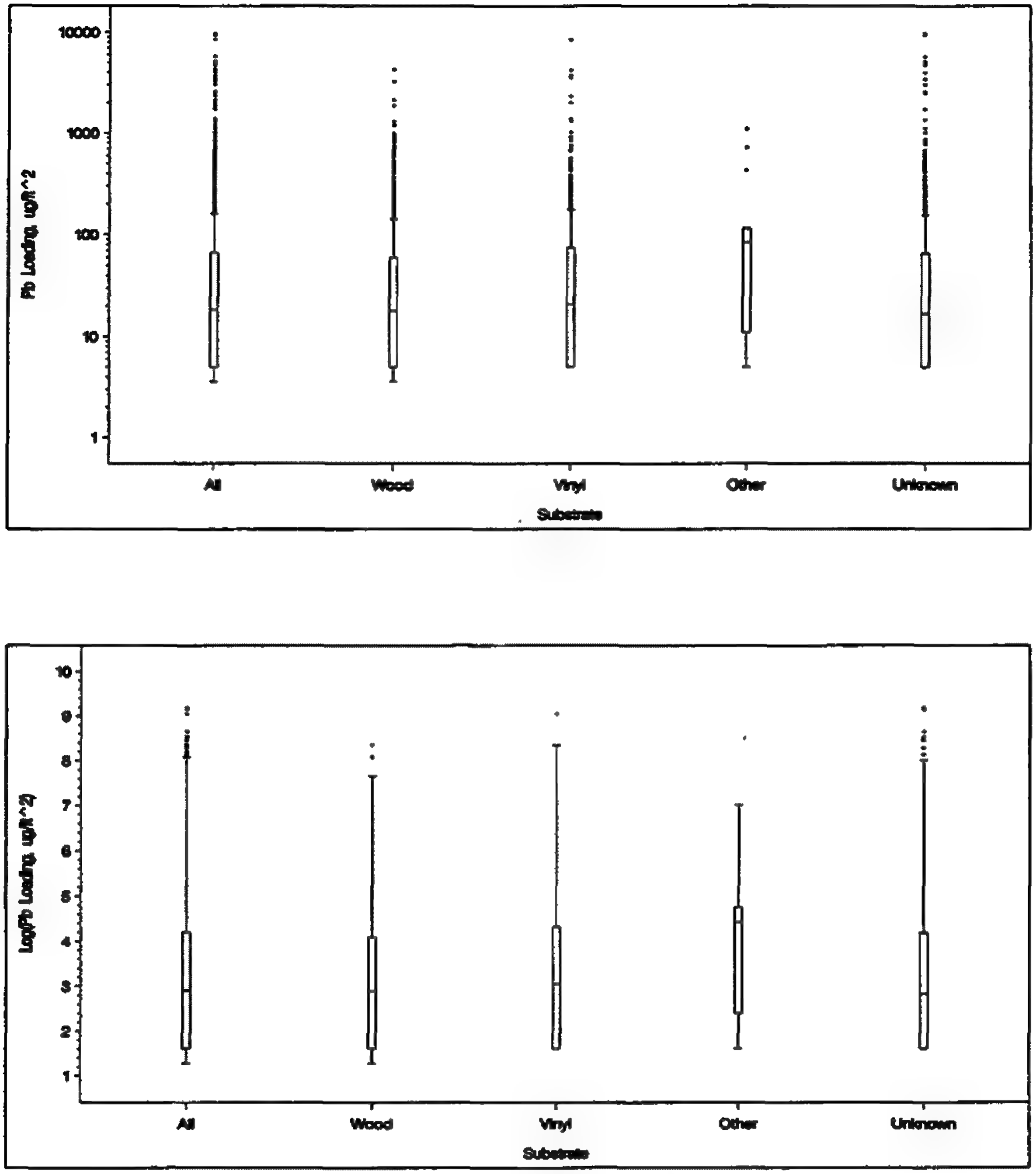


Figure I-4. **Box and Whisker Plots of the Distributions of Floors Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Maryland Data by Substrate for the First Site Visit**

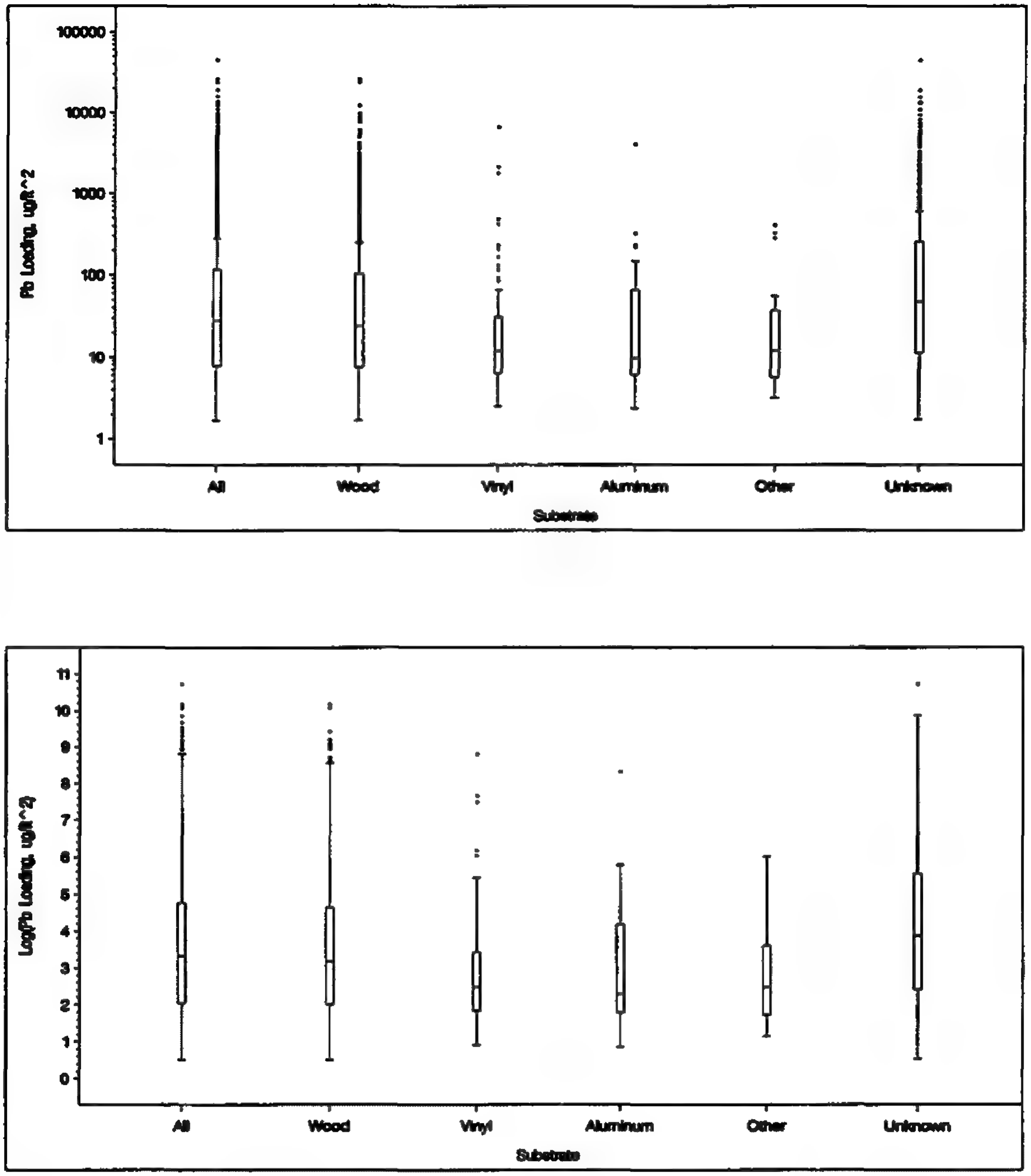


Figure I-5. **Box and Whisker Plots of the Distributions of Window Sills Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Maryland Data by Substrate for the First Site Visit**

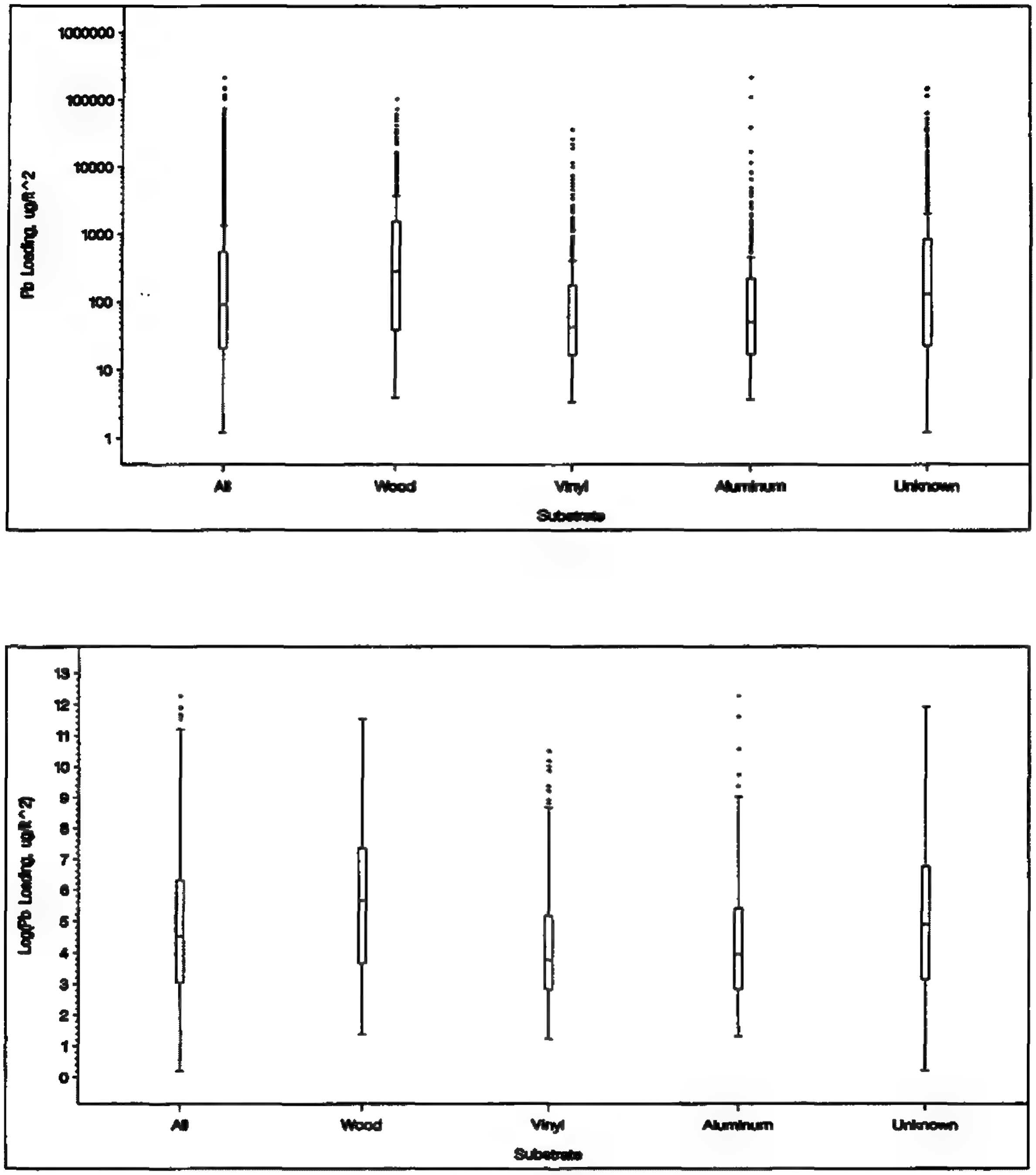


Figure I-6. **Box and Whisker Plots of the Distributions of Window Troughs Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Maryland Data by Substrate for the First Site Visit**

Table I-1. Percentiles ($\mu g/ft^2$) of the Clearance Data by Surface and Substrate for the First Site Visit for Dover and Maryland.

Data Source	Surface	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Dover	Floors	All	633	5	44	68	107	317
		Wood	3	31	61	61	61	61
		Vinyl	625	5	44	68	107	317
		Unknown	5	9	72	96	96	96
	Sills	All	18	443	1260	1620	2280	2280
		Wood	9	718	1260	1620	1620	1620
		Vinyl	1	212	212	212	212	212
		Aluminum	4	443	467	467	467	467
		Unknown	4	993	2280	2280	2280	2280
	Troughs	All	265	7	65	137	202	1830
		Vinyl	185	7	77	152	222	2040
		Aluminum	11	10	16	16	106	106
		Other	2	136	239	239	239	239
		Unknown	67	7	12	68	89	643
Maryland	Floors	All	2750	19	85	181	330	1130
		Wood	1082	18	77	159	297	892
		Vinyl	660	21	99	200	360	1400
		Other	19	84	116	725	1110	1110
		Unknown	989	17	82	182	347	2580
	Sills	All	2465	28	181	511	1370	5650
		Wood	1687	24	144	376	864	3590
		Vinyl	97	12	47	116	420	6620
		Aluminum	40	10	84	186	280	4080
		Other	18	12	55	327	406	406
		Unknown	623	48	439	1350	2790	9500
	Troughs	All	1985	92	844	3120	9480	49800
		Wood	458	283	2160	7300	16600	59600
		Vinyl	551	43	239	684	1530	10200
		Aluminum	286	51	337	983	2580	38900
		Unknown	690	133	1370	5700	15100	63800

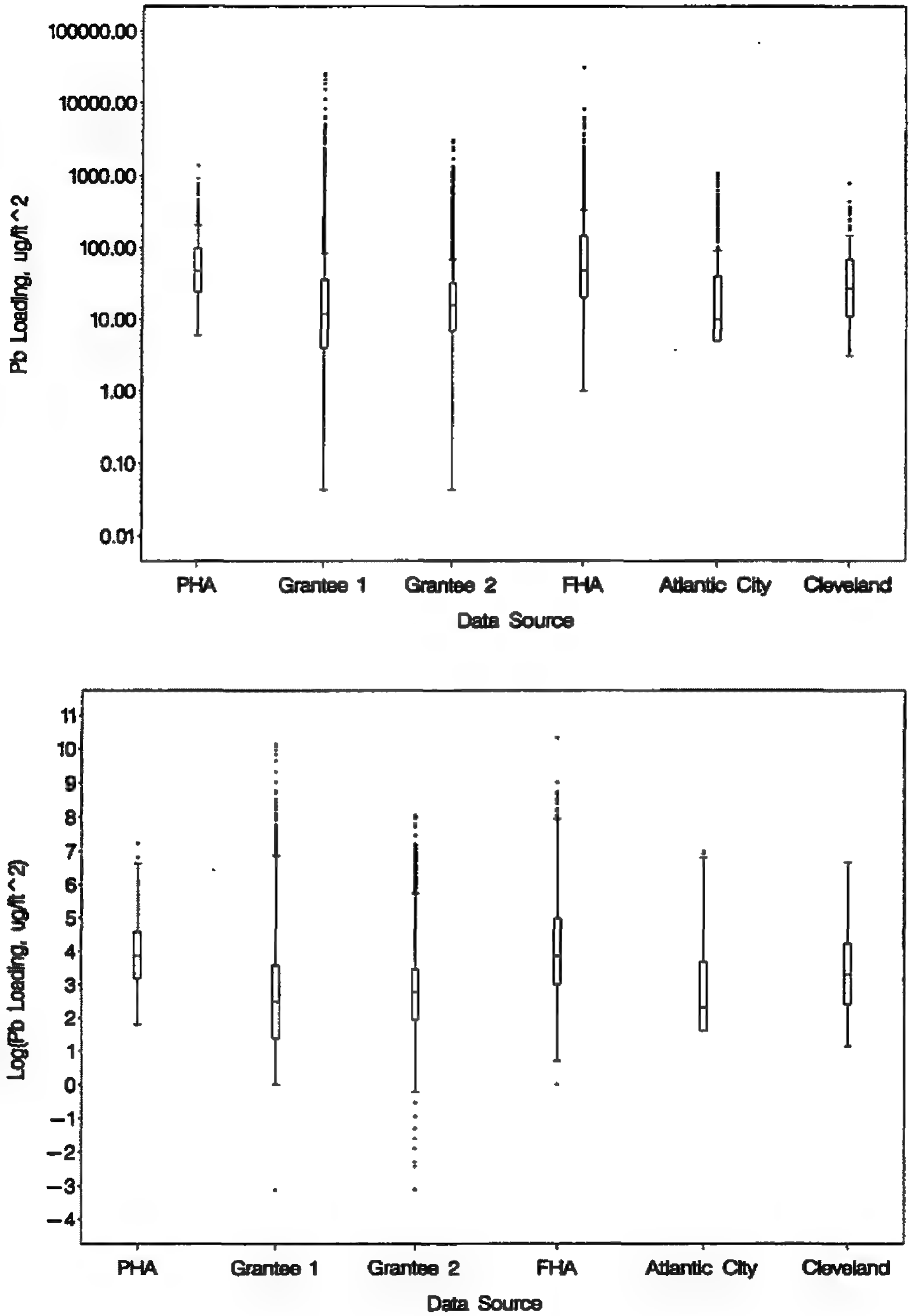


Figure I-7. Box and Whisker Plots of the Distributions of Floors Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings by Data Source for the First Site Visit

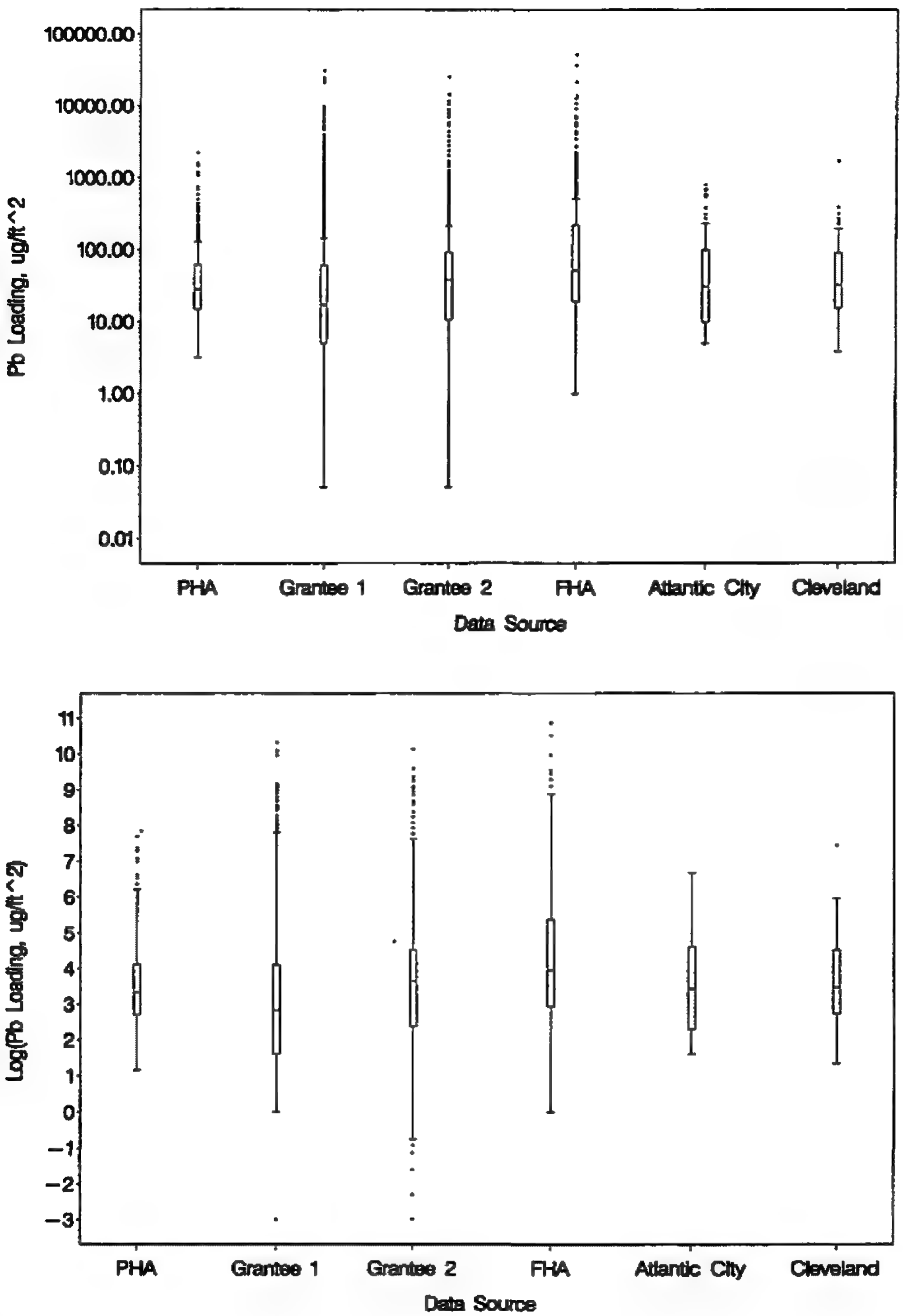


Figure I-8. Box and Whisker Plots of the Distributions of Window Sills Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings by Data Source for the First Site Visit

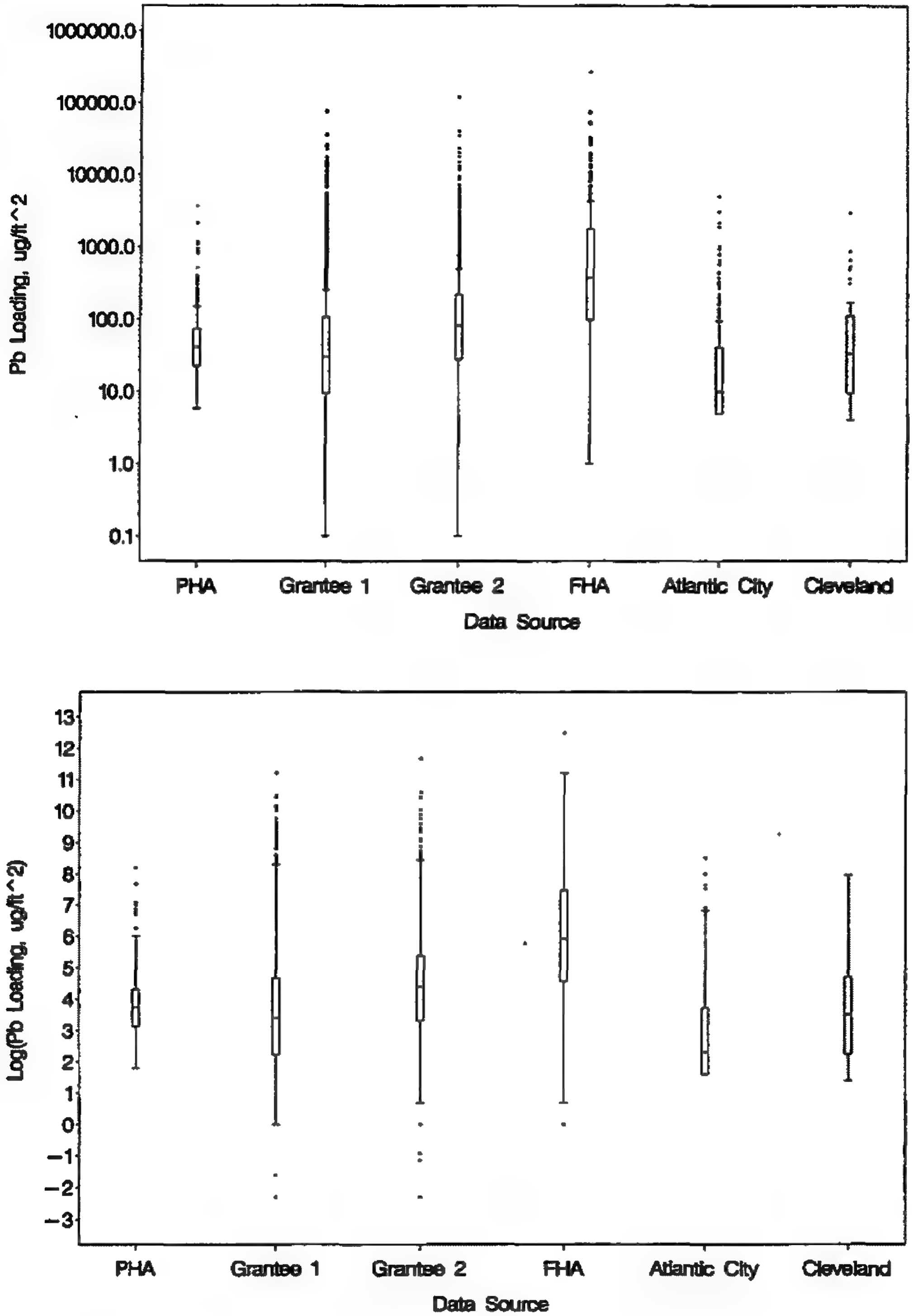
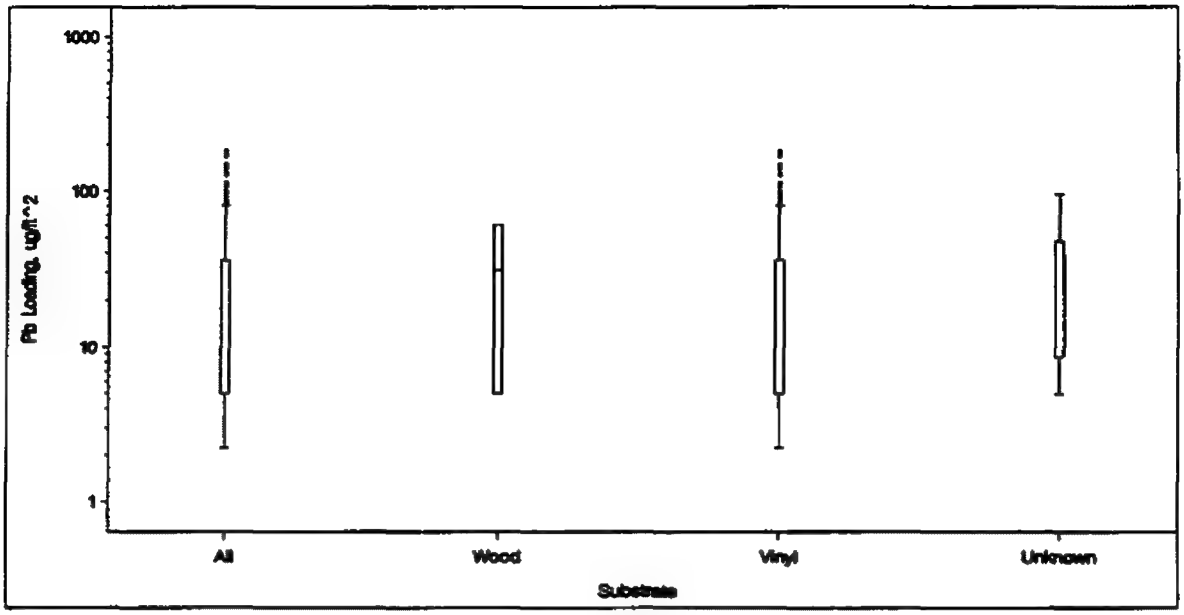


Figure I-9. Box and Whisker Plots of the Distributions of Window Troughs Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings by Data Source for the First Site Visit

Table I-2. Percentiles ($\mu g/ft^2$) of the Clearance Data by Surface and Data Sources for the First Site Visit.

Surface	Data Source	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Floors	PHA	558	48	111	200	312	600
	Grantee 1	8179	12	47	110	227	1030
	Grantee 2	3642	16	39	76	168	664
	FHA	967	48	187	418	871	3119
	Atlantic City	554	10	55	130	230	700
	Cleveland	158	27	87	190	320	440
Sills	PHA	411	28	80	175	281	1175
	Grantee 1	4798	17	84	202	418	1870
	Grantee 2	2147	38	106	171	356	1568
	FHA	668	52	271	714	1678	9054
	Atlantic City	51	31	150	380	660	790
	Cleveland	93	33	125	190	250	1700
Troughs	PHA	371	42	85	167	268	1089
	Grantee 1	3002	30	150	396	937	7600
	Grantee 2	1346	81	285	692	1527	7088
	FHA	442	375	2569	5810	9150	50534
	Atlantic City	258	10	70	190	450	2130
	Cleveland	39	33.3	170	530	850	2900



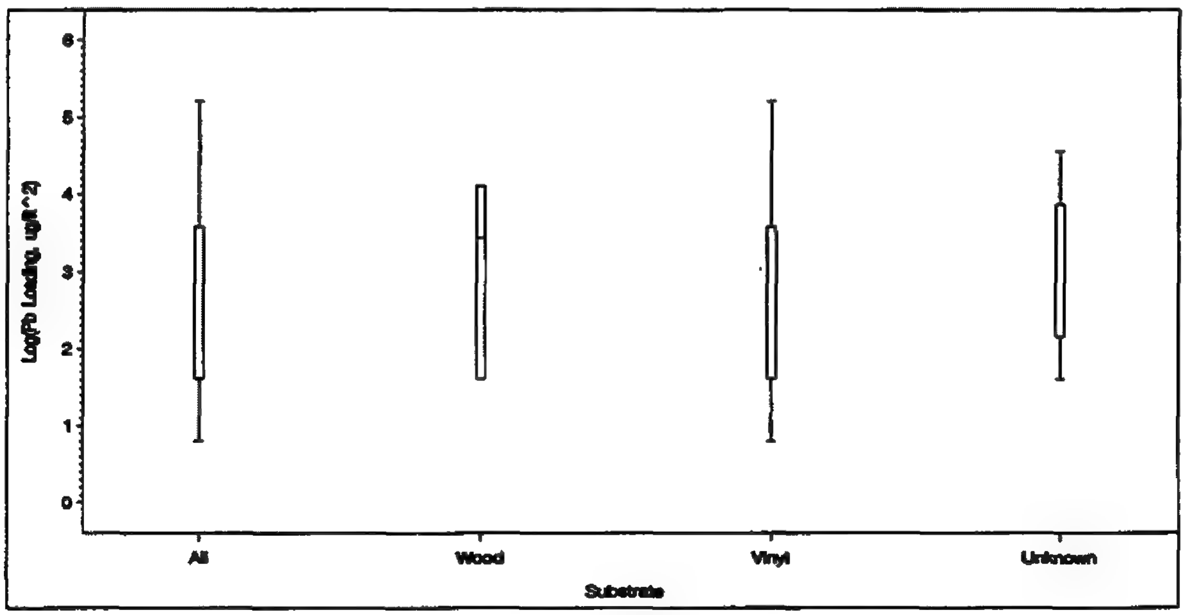


Figure I-10. Box and Whisker Plots of the Distributions of Floors Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Dover Data by Substrate for the Passed Clearance Visits

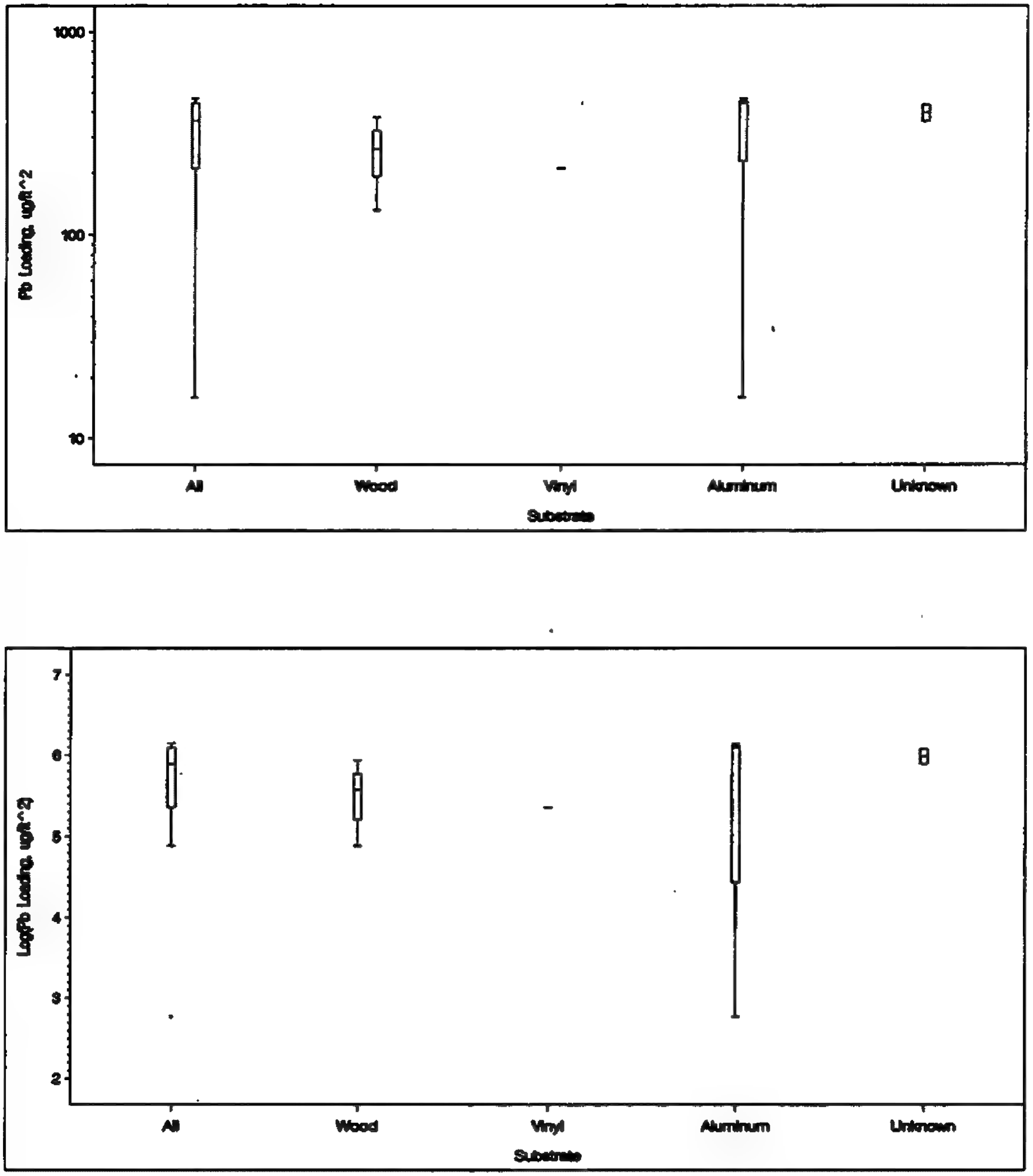


Figure I-11. Box and Whisker Plots of the Distributions of Window Sills Dust-Lead Loadings and In-Transformed Dust-Lead Loadings on Dover Data by Substrate for the Passed Clearance Visits

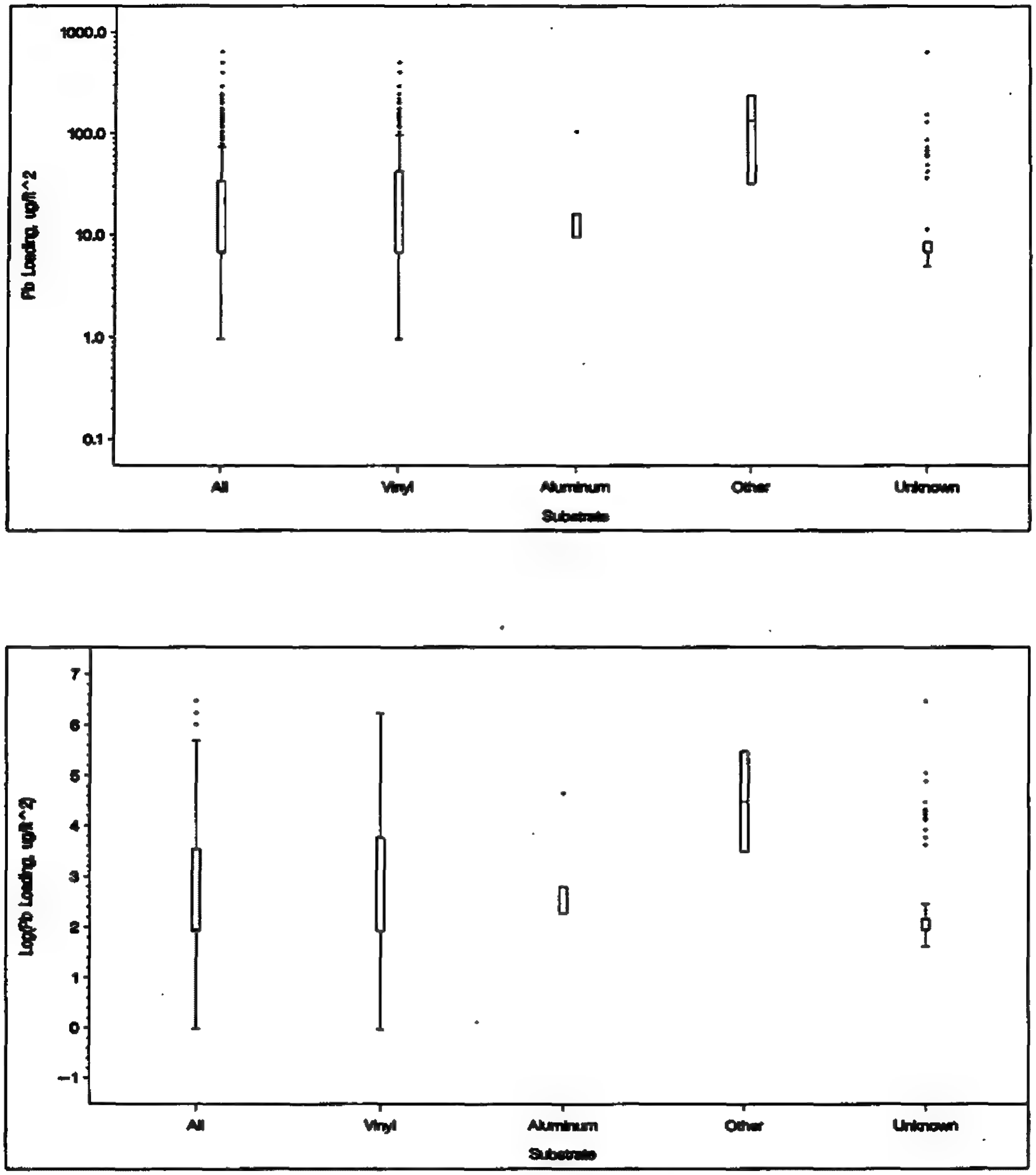


Figure I-12. Box and Whisker Plots of the Distributions of Window Troughs Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Dover Data by Substrate for the Passed Clearance Visits

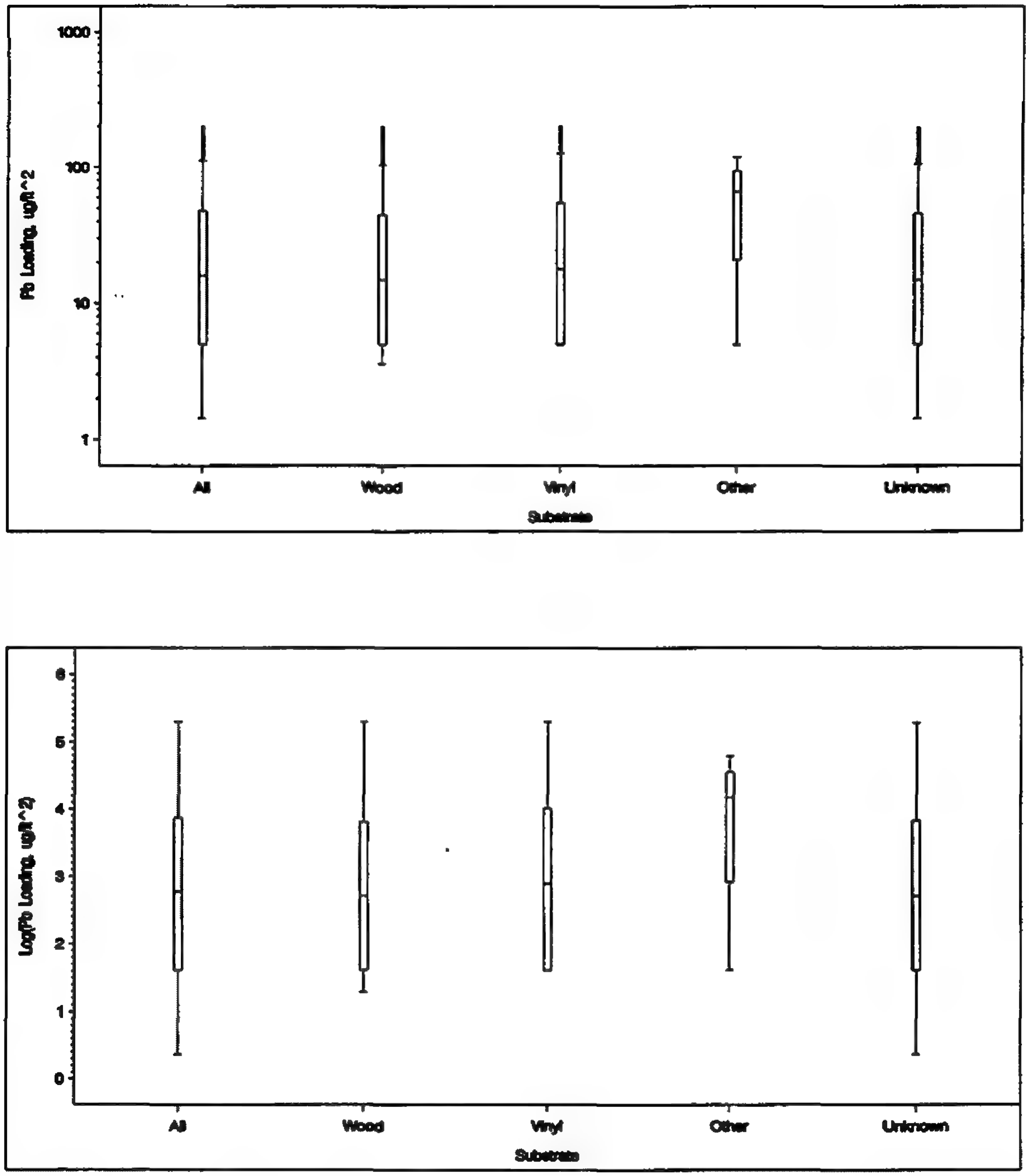


Figure I-13. Box and Whisker Plots of the Distributions of Floors Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Maryland Data by Substrate for the Passed Clearance Visits

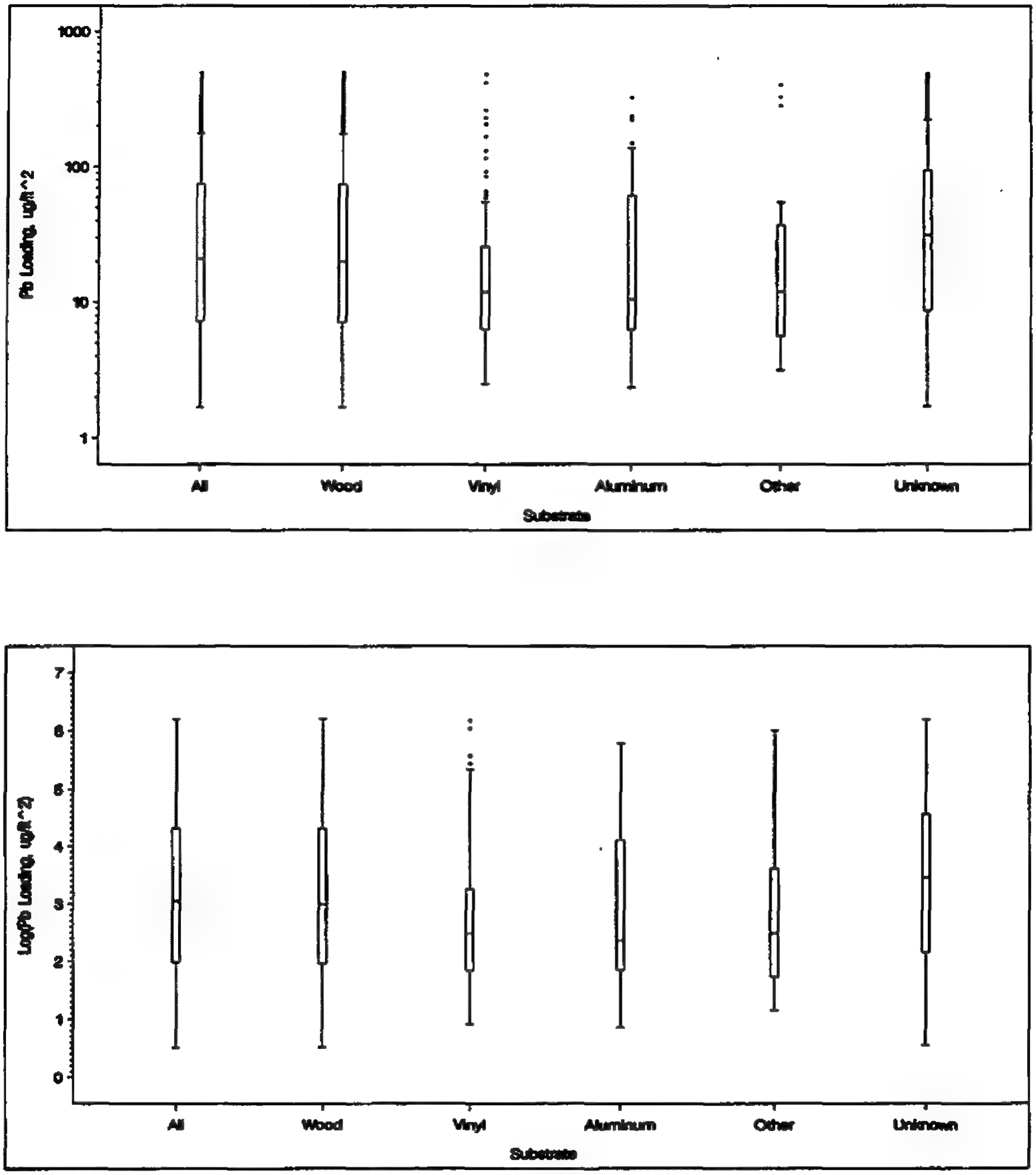


Figure I-14. Box and Whisker Plots of the Distributions of Window Sills Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Maryland Data by Substrate for the Passed Clearance Visits

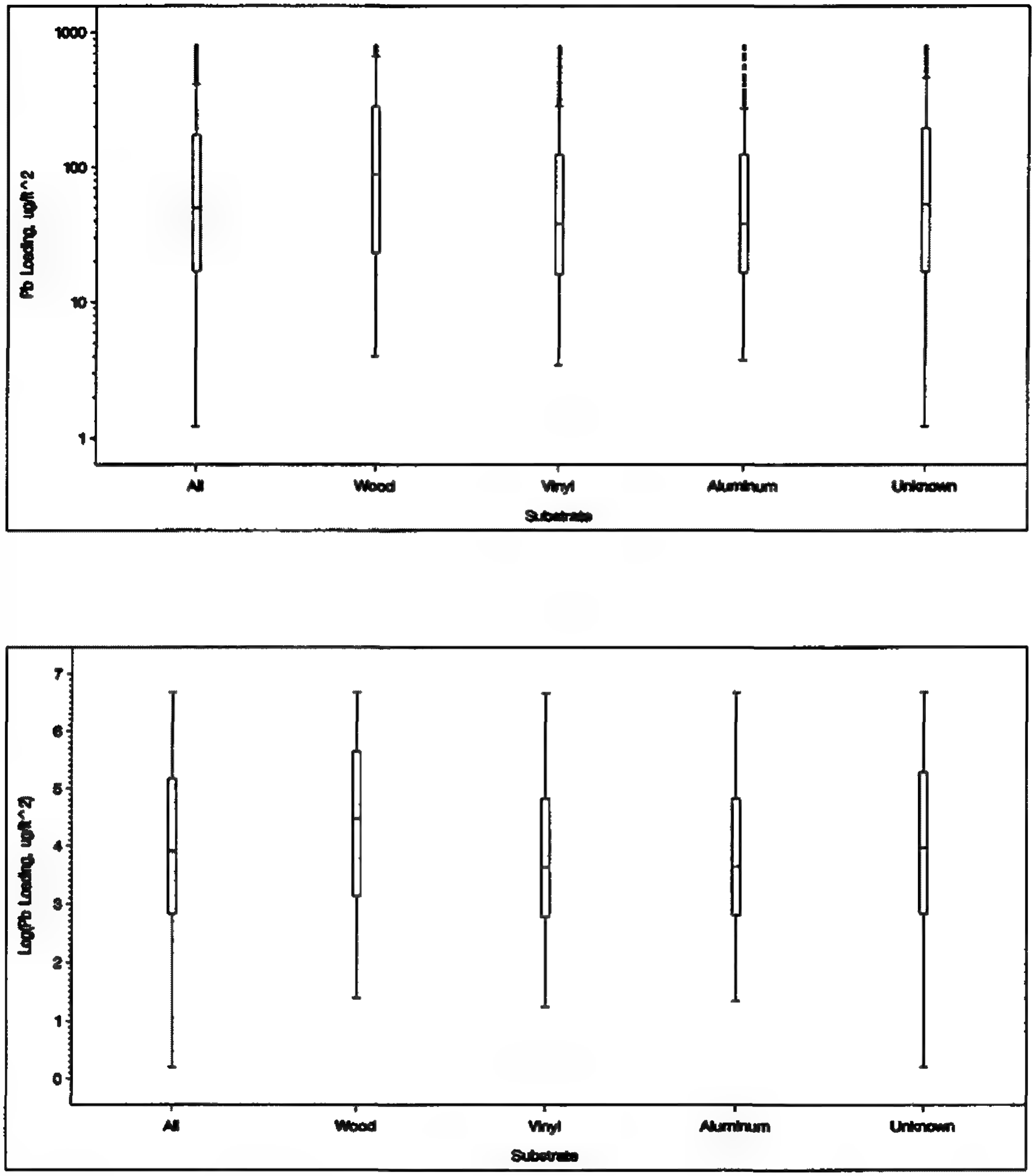


Figure I-15. Box and Whisker Plots of the Distributions of Window Troughs Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings on Maryland Data by Substrate for the Passed Clearance Visits

Table I-3. Percentiles ($\mu g/ft^2$) of the Passed Clearance Data by Surface and Substrate for Lead Loading Results for Dover and Maryland.

Data Source	Surface	Substrate	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile
Dover	Floors	All	620	5	43	61	82
		Wood	3	31	61	61	61
		Vinyl	612	5	43	60	81
		Unknown	5	9	72	96	96
	Sills	All	11	361	443	443	467
		Wood	4	262	377	377	377
		Vinyl	1	212	212	212	212
		Aluminum	4	443	467	467	467
		Unknown	2	398	434	434	434
	Troughs	All	260	7	59	111	157
		Vinyl	180	7	67	140	169
		Aluminum	11	10	16	16	106
		Other	2	136	239	239	239
		Unknown	67	7	12	68	89
Maryland	Floors	All	2712	16	60	98	128
		Wood	1052	15	58	88	121
		Vinyl	651	18	69	106	135
		Other	20	67	105	116	118
		Unknown	989	15	56	98	134
	Sills	All	2411	21	101	201	295
		Wood	1651	20	99	193	295
		Vinyl	106	12	37	66	167
		Aluminum	44	11	83	149	234
		Other	18	12	55	327	406
		Unknown	592	32	119	238	315
	Troughs	All	1827	50	231	400	571
		Wood	373	88	338	530	655
		Vinyl	575	38	163	308	515
		Aluminum	282	38	168	322	456
		Unknown	597	53	257	412	604

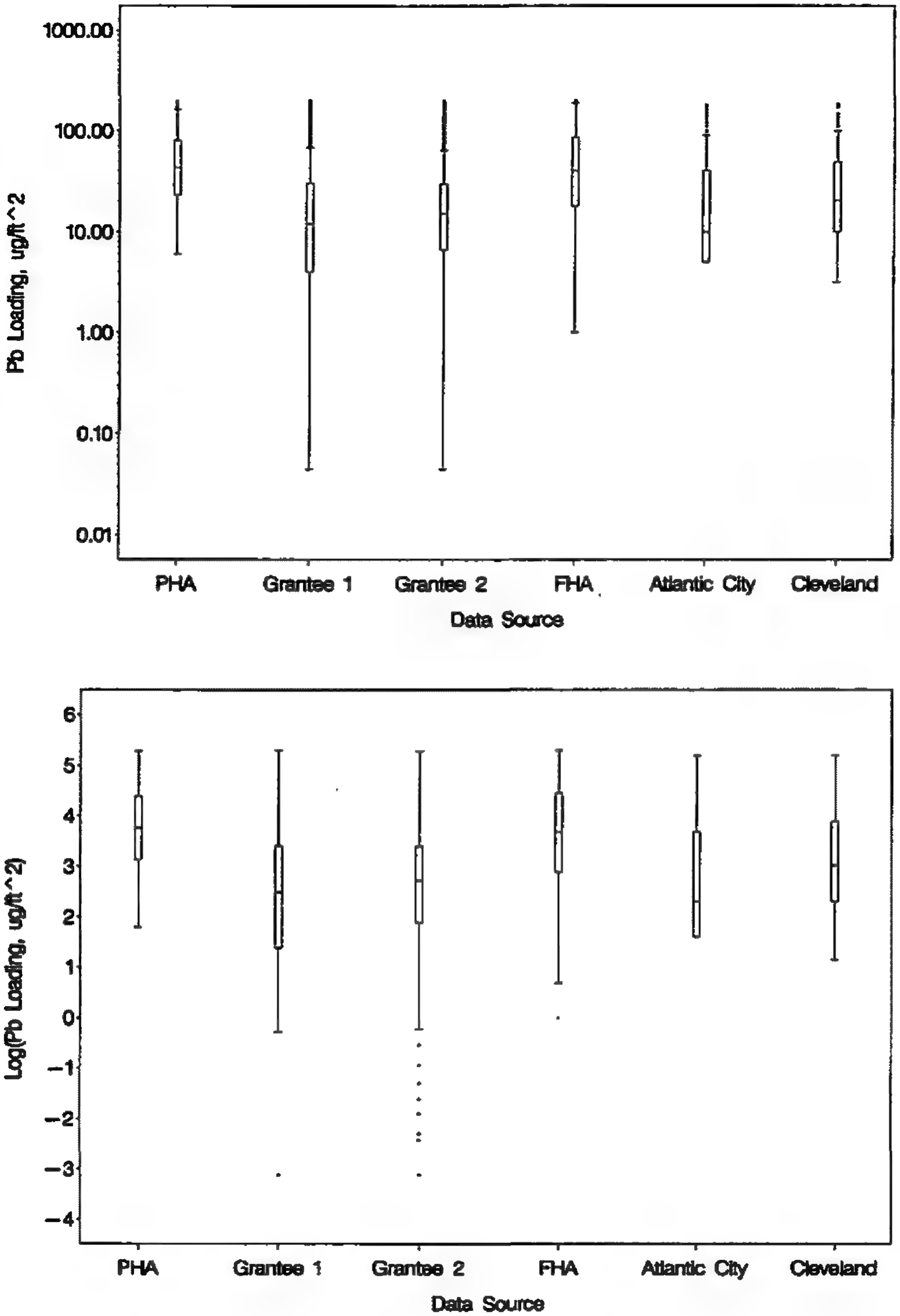


Figure I-16. Box and Whisker Plots of the Distributions of Floors Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings by Data Source for the Passed Clearance Visits

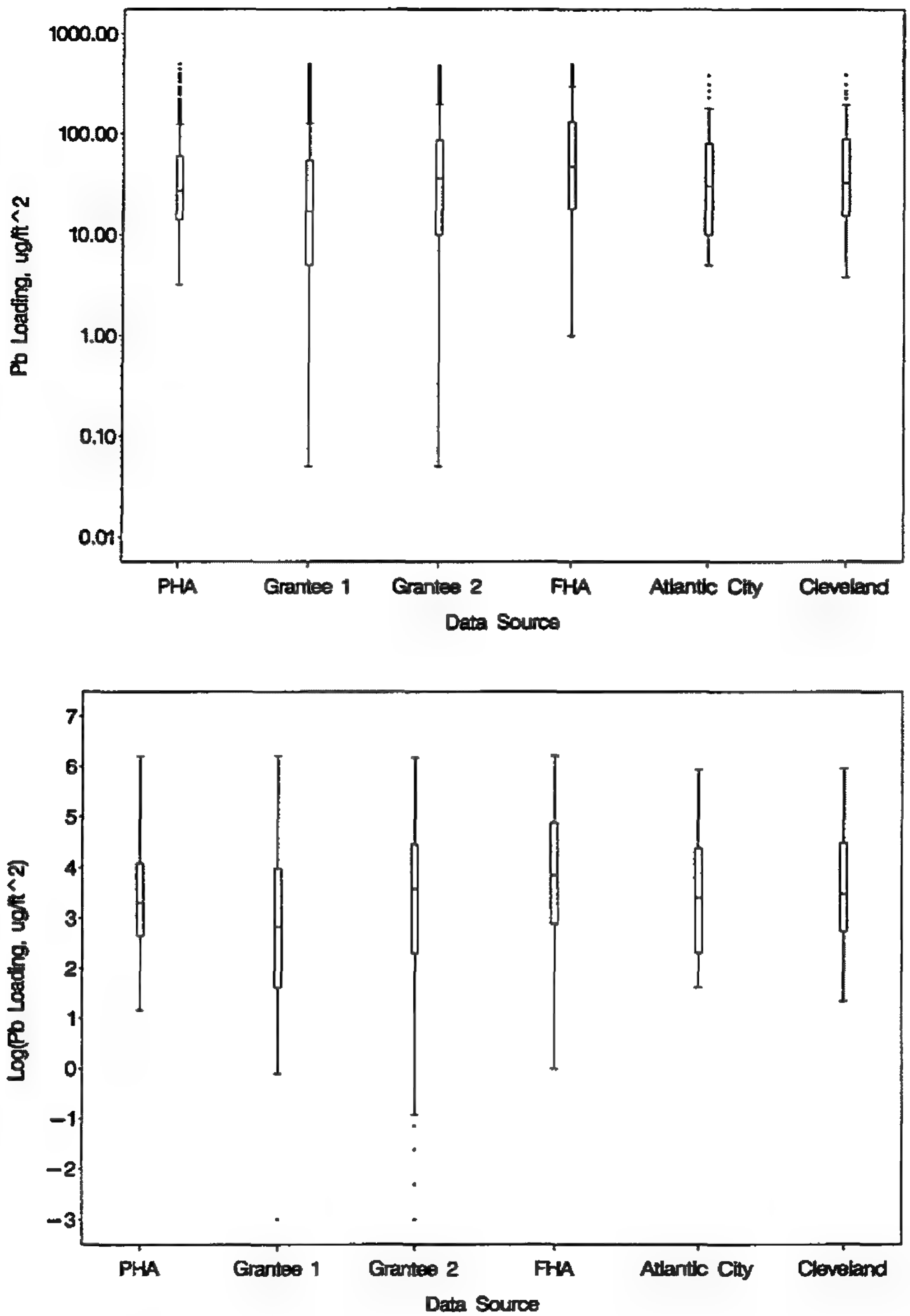


Figure I-17. Box and Whisker Plots of the Distributions of Window Sills Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings by Data Source for the Passed Clearance Visits

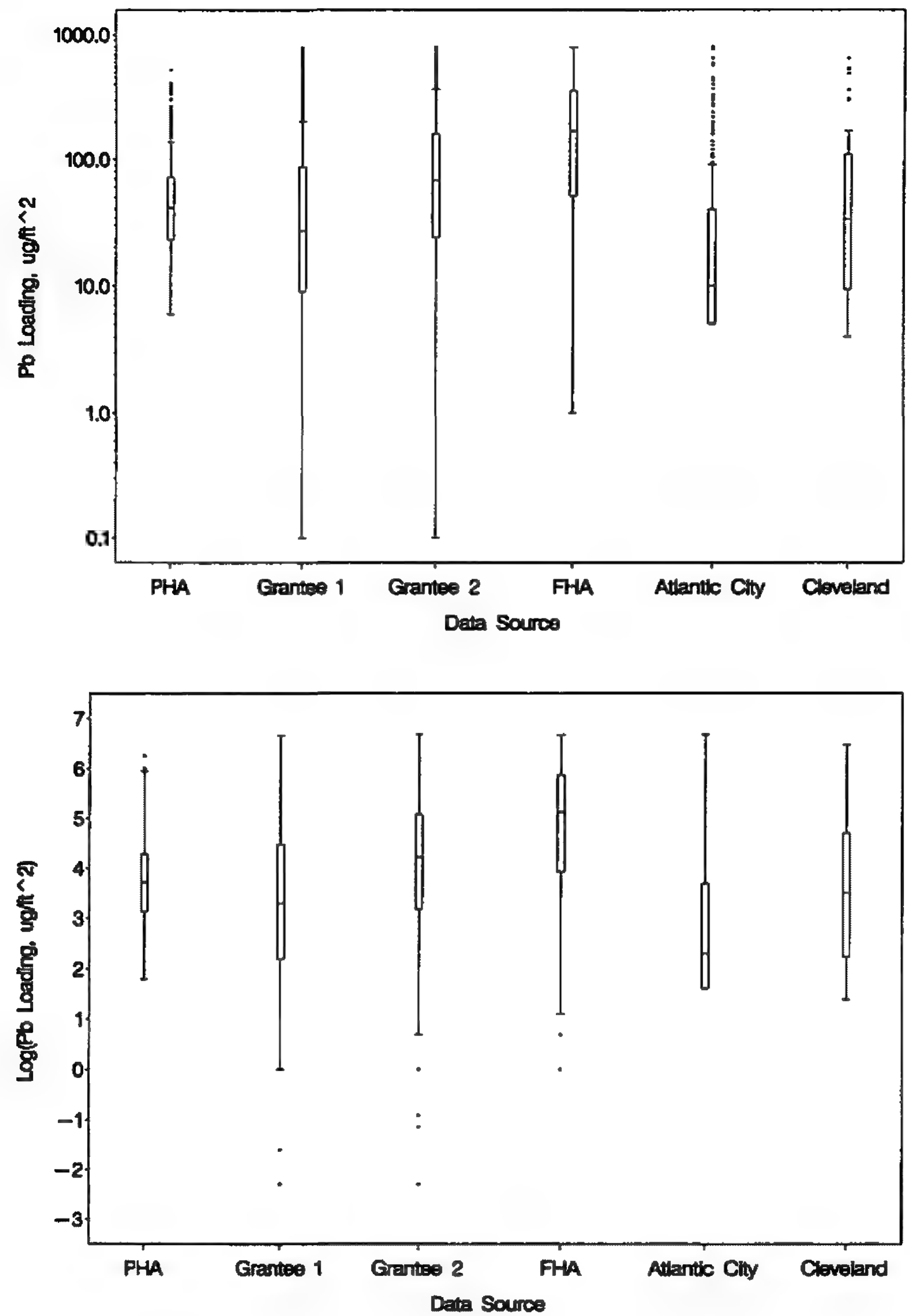


Figure I-18. **Box and Whisker Plots of the Distributions of Window Troughs Dust-Lead Loadings and ln-Transformed Dust-Lead Loadings by Data Source for the Passed Clearance Visits**

Table I-4. Percentiles ($\mu g/ft^2$) of the Passed Clearance Visits by Surface and Data Sources for Lead Loading Results.

Surface	Data Source	Sample Size	50th Percentile	80th Percentile	90th Percentile	95th Percentile	99th Percentile
Floors	PHA	554	43	93	118	148	185
	Grantee 1	8345	12	39	70	108	173
	Grantee 2	3749	15	34	57	90	163
	FHA	997	40	102	141	165	191
	Atlantic City	545	10	46	80	120	170
	Cleveland	161	22	64	110	134	182
Sills	PHA	412	27	68	150	222	378
	Grantee 1	4906	17	72	141	236	410
	Grantee 2	2170	36	99	145	215	372
	FHA	689	47	164	263	358	481
	Atlantic City	46	30	90	180	270	380
	Cleveland	93	32	120	170	230	388
Troughs	PHA	371	41	81	138	213	399
	Grantee 1	3036	27	116	237	389	691
	Grantee 2	1341	68	198	346	512	725
	FHA	423	169	431	598	678	760
	Atlantic City	267	10	66	170	320	650
	Cleveland	39	33	170	490	540	648

APPENDIX J

Comparison of Clearance Guidance

APPENDIX J

COMPARISON OF CLEARANCE GUIDANCE

The following is a comparison of the guidance on clearance in the 1990 HUD Interim Guidelines [2], the 1995 EPA 403 Guidance [5], the 1995 HUD Guidelines [3], the 1996 EPA 402/404 Rule [4], the 1999 HUD 1012/1013 Final Rule [22], and the 2001 EPA 403 Final Rule [1]. Table J-1 presents a comparison of the number and location of samples for single sample and composite sample testing in contained and non-contained areas. Clearance testing procedures for visual inspections are shown in Table J-2, procedures for sealants are in Table J-3, and waiting times for conducting clearance testing are compared in Table J-4. Clearance standards are outlined in Table J-5, failure procedures in Table J-6, a comparison of the units in which to report samples is presented in Table J-7, compositing rules given in Table J-8, and conflict of interest issues are compared in Table J-9.

Below are some of the major changes that have taken place in clearance standards over time.

- 1990 HUD Interim Guidelines [2] clearance standards are 200 $\mu g/ft^2$ for bare floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window wells (troughs).

- 1994 EPA 403 Guidance [5] clearance standards are 100 $\mu g/ft^2$ for bare floors, 500 $\mu g/ft^2$ for interior window sills, and 800 $\mu g/ft^2$ for exterior window sills (troughs) and exterior horizontal surfaces.

- 1995 EPA 403 Guidance was the same as 1994 EPA 403 Guidance, but was disseminated as a Federal Register Notice [5].

- 1995 HUD Guidelines [3] clearance standards are 100 $\mu g/ft^2$ for floors (including carpeted and uncarpeted floors), 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window wells (troughs) and exterior concrete or other rough surfaces.

- 1996 EPA 402/404 Rule [4] refers to the clearance levels in the EPA Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust and Lead Contaminated Soil or other equivalent guidelines.

- 1999 HUD 1012/1013 Final Rule [22] dust-lead clearance standards are 40 $\mu g/ft^2$ for floors (including carpeted and uncarpeted interior floors), 250 $\mu g/ft^2$ for interior window sills, and 800 $\mu g/ft^2$ for window troughs.

- 2001 EPA 403 Final Rule [1] dust-lead clearance standards are 40 $\mu g/ft^2$ for floors (including carpeted and uncarpeted floors), 250 $\mu g/ft^2$ for interior window sills, and 400 $\mu g/ft^2$ for window troughs.

Table J-1. Comparison of HUD and EPA Clearance Guidance and Rule Documents for Single Samples and Composite Samples Taken in Contained and Non-Contained Areas.

	Single Samples		Composited Samples		
	Contained area	Non Contained area	Contained area	Non Contained area	Other Samples
1990 HUD Interim Guidelines [2]	**Onsite paint removal:** 3 wipe samples in each area abated: 1 floor 1 sill 1 well AND 1 sample outside containment area, within 10ft. (In 20% of multifamily and all single family units); **Replacement and/or encapsulation ONLY:** 1 wipe sample in each abated area, divided equally between floors, sills and wells AND 1 wipe sample outside the containment area (within 10ft)	**Onsite paint removal:** 3 wipe samples in each room or area: 1 floor 1 window sill 1 window well In 20% of the abated units for *multifamily and all single family;* **Replacement and/or encapsulation ONLY:** 1 wipe sample in each area, divided equally between floors, sills and wells.			**Exterior abatement:** at least 1 wipe test on a horizontal surface in part of outdoor living area

Table J-1. Comparison of HUD and EPA Clearance Guidance and Rule Documents for Single Samples and Composite Samples Taken in Contained and Non-Contained Areas (Continued).

	Single Samples		Composited Samples		
	Contained area	Non Contained area	Contained area	Non Contained area	Other Samples
1994/1995 EPA 403 Guidance [5]	Most of the clearance sampling should be conducted within the containment area. Collect 1 floor sample outside the containment area but within 10 feet of airlock If on-site paint removal took place in the interior, for each room designated for sampling collect: 1 floor sample 1 interior window sill sample 1 exterior window sill sample If no on-site paint removal took place in the interior, for each room designated for sampling collect: 1 floor sample 1 window sill sample (either interior or exterior) If exterior paint abatement or interim controls were performed collect: 1 exterior window sill sample 1 other horizontal surface in a living area or near an entryway for testing. (Preferably from the sides or exterior area of the house.)	All interior rooms or areas should be sampled. If on-site paint removal took place in the interior, for each room designated for sampling collect: 1 floor sample 1 interior window sill sample 1 exterior window sill sample If no on-site paint removal took place in the interior, for each room designated for sampling collect: 1 floor sample 1 window sill sample (either interior or exterior) If exterior paint abatement or interim controls were performed collect: 1 exterior window sill sample 1 other horizontal surface in a living area or near an entryway for testing. (Preferably from the sides or exterior area of the house.)		Composite sampling not discussed in this document	No samples other than single samples were discussed

Table J-1. Comparison of HUD and EPA Clearance Guidance and Rule Documents for Single Samples and Composite Samples Taken in Contained and Non-Contained Areas (Continued).

	Single Samples		Composited Samples		
	Contained area	Non Contained area	Contained area	Non Contained area	Other Samples
1995 HUD Guidelines [3]	2 samples from at least four rooms (whether treated or untreated). 1 interior window sill or trough, alternating between rooms, 1 floor AND 1 floor sample outside the containment area within 10 ft of airlock. (Recommended in 20% of the multifamily and ALL single-family homes) AND for common areas, 1 floor sample for every 2000 ft^2 of a common area room floor.	2 samples from at least four rooms in the dwelling (treated or untreated): 1 interior window sill or trough, alternating between rooms 1 floor AND for common areas, 1 floor sample for every 2000 ft^2 of a common area room floor.	3 composite samples from at least four rooms in dwellings (whether treated or untreated): 1 floor composite; 1 window sill composite; 1 window trough composite AND 1 floor sample outside containment area within 10 ft of airlocks. (Recommended in 20% of multifamily and ALL single-family homes); AND for common areas: 1 floor subsample for every 2000 ft^2 (up to 8000 ft^2 for each composite)	3 composite samples from at least four rooms in dwellings (treated or untreated): 1 floor composite; 1 interior window sill composite; 1 window trough composite For common areas: 1 floor subsample for every 2000 ft^2; up to 8000 ft^2 can be sampled for each composite.	**Exterior treatment:** 2 dust samples: At least 1 on a horizontal surface in part of the outdoor living area (porch or entryway); 1 window trough sample on each floor where exterior work was performed. 1 additional trough sample should be collected from a few lower floors.
1999 HUD 1012/1013 Final Rule [22]	Dust samples shall be collected and analyzed in accordance with standards established either by a State or Indian tribe under a program authorized by EPA in accordance with 40 CFR part 745, subpart Q, or by the EPA in accordance with 40 CFR 745.227 (both are part of the 1996 EPA 402/404 Rule [4]).				

Table J-1. Comparison of HUD and EPA Clearance Guidance and Rule Documents for Single Samples and Composite Samples Taken in Contained and Non-Contained Areas (Continued).

	Single Samples		Composited Samples		
	Contained area	Non Contained area	Contained area	Non Contained area	Other Samples
1996 EPA 402/404 Rule [4]	1 dust sample from window (if available) 1 dust sample from floor of no less than 4 rooms, hallways, or stairwells, within the containment area. 1 dust sample taken from floor outside the containment area. [If there are less than 4 rooms, hallways, or stairwells within the containment area, then all rooms, hallways, or stairwells shall be sampled.]	2 dust samples from no less than 4 rooms, hallways, stairwells in the residential dwelling or child-occupied facility. 1 dust sample from window (if available) of each room, hallway or stairwell selected. 1 dust sample from floor of each room, hallway or stairwell selected. [If there are less than 4 rooms, hallways, or stairwells then all rooms, hallways, or stairwells shall be sample.]	Clearance sampling may be conducted by employing single-surface sampling or composite sampling techniques.	Clearance sampling may be conducted by employing single-surface sampling or composite sampling techniques.	Following exterior paint abatement, a visible inspection shall be conducted. All horizontal surfaces in the outdoor living area closest to the abated surface shall be found to be cleaned of visible dust and debris. In addition, a visual inspection shall be conducted to determine the presence of paint chips in the dripline or next to the foundation below any exterior surface abated.
2001 EPA 403 Final Rule [1]	1 dust sample from interior window sill and 1 from window trough (if present) 1 dust sample from floors of each of no less than 4 rooms, hallways, or stairwells, within the containment area. 1 dust sample taken from floor outside the containment area. [If there are less than 4 rooms, hallways, or stairwells within the containment area, then all rooms, hallways, or stairwells shall be sampled.]	2 dust samples from each of no less than 4 rooms, hallways, stairwells in the residential dwelling or child-occupied facility. 1 dust sample from interior window sill and window trough (if present). 1 dust sample from floor of each room, hallway or stairwell selected. [If there are less than 4 rooms, hallways, or stairwells then all rooms, hallways, or stairwells shall be sample.]	Clearance sampling may be conducted by employing single-surface sampling or composite sampling techniques.	Clearance sampling may be conducted by employing single-surface sampling or composite sampling techniques.	Addressed in the 1996 EPA 402/404 Rule [4], 40 CFR §745.227 (e)(8)(v)(C).

Table J-2. Comparison of Procedures for Visual Inspections from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Visual Inspections
1990 HUD Interim Guidelines [2]	Perform visual inspection after abatement but before repainting. Surface dust sampling should not be conducted if there is a visible accumulation of dust or debris
1995 EPA 403 Guidance [5]	All interior rooms or areas and exterior areas should be visually clean before collecting dust samples. If this is not the case, clean the rooms and areas before starting dust collection for clearance testing
1995 HUD Guidelines [3]	Room by room while environmental samples taken. Prior to repainting No evidence of settled dust
1999 HUD 1012/1013 Final Rule [22]	The visual assessment shall be performed to determine if deteriorated paint surfaces and/or visible amounts of dust, debris, paint chips or other residue are still present. Both exterior and interior painted surfaces shall be examined for the presence of deteriorated paint. If deteriorated paint or visible dust, debris or residue are present in areas subject to dust sampling, they must be eliminated prior to the continuation of the clearance examination, except elimination of deteriorated paint is not required if it has been determined, through paint testing or a lead-based paint inspection, that the deteriorated paint is not lead-based paint. If exterior painted surfaces have been disturbed by the hazard reduction, maintenance or rehabilitation activity, the visual assessment shall include an assessment of the ground and any outdoor living areas close to the affected exterior painted surfaces. Visible dust or debris in living areas shall be cleaned up and visible paint chips on the ground shall be removed.
1996 EPA 402/404 Rule [4]	A visual inspection shall be performed to determine if deteriorated painted surfaces and/or visible amounts of dust, debris or residue are still present. If deteriorated painted surfaces or visible amounts of dust, debris or residue are present, these conditions must be eliminated prior to the continuation of the clearance procedures.
2001 EPA 403 Final Rule [1]	Addressed in the 1996 EPA 402/404 Rule [4], 40 CFR §745.227 (e)(8)(i).

Table J-3. Comparison of Procedures for Sealants from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Sealant
1990 HUD Interim Guidelines [2]	Painting or otherwise sealing abated surfaces and all interior floors is the next step of cleaning process. All abated surfaces, including walls, ceilings, and woodwork, should be primed with an appropriate primer. All applicable areas may then be repainted. Wooden floors, vinyl tile, linoleum, and concrete floors should be sealed.
1995 EPA 403 Guidance [5]	Document does not address the use of sealants for clearance.
1995 HUD Guidelines [3]	Seal floors before clearance testing
1999 HUD 1012/1013 Final Rule [22]	Document does not address the use of sealants for clearance.
1996 EPA 402/404 Rule [4]	Document does not address the use of sealants for clearance.
2001 EPA 403 Final Rule [1]	Document does not address the use of sealants for clearance.

Table J-4. Comparison of Procedures for Waiting Time from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Waiting Time
1990 HUD Interim Guidelines [2]	Dust sampling should take place no sooner than 24 hr. after completion of post-abatement cleanup activities.
1995 EPA 403 Guidance [5]	Sampling of dust should take place at least one hour after completion of all abatement and interim control work, including cleanup.
1995 HUD Guidelines [3]	Wait one hour after cleaning.
1999 HUD 1012/1013 Final Rule [22]	In accordance with 40 CFR 745.227(e)(8). This is part of the 1996 EPA 402/404 Rule [4].
1996 EPA 402/404 Rule [4]	Dust samples for clearance purposes shall be taken a minimum of 1 hour after completion of final post-abatement cleanup activities.
2001 EPA 403 Final Rule [1]	Addressed in the 1996 EPA 402/404 Rule [4], 40 CFR §745.227 (e)(8)(iv).

Table J-5. Comparison of Clearance Standards from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Clearance Standards
1990 HUD Interim Guidelines [2]	200 $\mu g/ft^2$ for bare floors 500 $\mu g/ft^2$ for window sills 800 $\mu g/ft^2$ for window wells (troughs)
1995 EPA 403 Guidance [5]	100 $\mu g/ft^2$ for bare floors 500 $\mu g/ft^2$ for interior window sills 800 $\mu g/ft^2$ for exterior window sills (troughs) and exterior horizontal surfaces
1995 HUD Guidelines [3]	100 $\mu g/ft^2$ for floors (including carpeted and uncarpeted floors) 500 $\mu g/ft^2$ for window sills, 800 $\mu g/ft^2$ for window wells (troughs) and exterior concrete or other rough surfaces.
1996 EPA 402/404 Rule [4]*	Clearance levels which are appropriate for the purposes of this section may be found in the EPA Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust and Lead Contaminated Soil or other equivalent guidelines. [5, 23]
1999 HUD 1012/1013 Final Rule [22]	40 $\mu g/ft^2$ for floors (carpeted or uncarpeted interior floors), 250 $\mu g/ft^2$ for interior window sills, 800 $\mu g/ft^2$ for window troughs
2001 EPA 403 Final Rule [1]	40 $\mu g/ft^2$ for floors (including carpeted and uncarpeted floors), 250 $\mu g/ft^2$ for interior window sills, 400 $\mu g/ft^2$ for window troughs.

* 1998 EPA 403 Proposed Rule [24] included proposed amendments to the final Section 402 rules for post-abatement dust clearance standards: 50 $\mu g/ft^2$ for uncarpeted floors, 250 $\mu g/ft^2$ for interior window sills, and 800 $\mu g/ft^2$ for window troughs.

Table J-6. Comparison of Failure Procedures from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Failure Procedure
1990 HUD Interim Guidelines [2]	If any of the residual lead dust level results exceeds the clearance criteria, the area must be cleaned again and re-tested until the criteria are met. All areas must pass clearance to be re-occupied.
1995 EPA 403 Guidance [5]	Samples above or equal to the appropriate standard have failed clearance, and all rooms or areas represented by those samples are said to have failed. For samples that have failed, the components represented by those samples (floors, interior window sills, exterior window sills, exterior horizontal surfaces, or interior areas outside a containment area) must be recleaned and retested. The process continues until clearance is obtained for all components.
1995 HUD Guidelines [3]	If the dust sample for any surface is above the standard, all similar surfaces in the dwelling that sample represents (e.g., all interior sills or floor) should be re-cleaned and re-tested. Only the similar component needs to be re-cleaned. If a surface fails twice additional LHC measures and/or further sealing should be considered.
1999 HUD 1012/1013 Final Rule [22]	All surfaces represented by a failed clearance sample shall be recleaned or treated by hazard reduction, and retested, until the applicable clearance level is met.
1996 EPA 402/404 Rule [4]	If the residual lead levels in a dust sample exceed the clearance levels, all the components represented by the failed sample shall be re-cleaned or treated by lead hazard reduction and re-tested until clearance levels are met.
2001 EPA 403 Final Rule [1]	If a property fails clearance, it must be recleaned until it passes, although it is not automatically necessary to reclean the entire property when clearance fails, such as when some of the visual and dust-testing clearance results have indicated that portions of the property are already clearned.

Table J-7. Comparison of Concentrations versus Loadings from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Concentration vs. Loading
1990 HUD Interim Guidelines [2]	The surface dust sampling method which is currently recommended is surface wipe sampling (i.e., loadings).
1995 EPA 403 Guidance [5]	The basic method for collecting dust clearance samples is the wipe method (i.e., loadings). Other dust collection methods may be used provided the user establishes comparability to the wipe method and is responsible for providing comparable standards for clearance. Note that when assessing multiple sources of lead, dust lead concentration may be a more appropriate measurement. The utility of concentration measurements for identifying hazardous room dust will be further considered in the development of section 403 rule making
1995 HUD Guidelines [3]	Until the EPA standards and protocols are established, wipe sampling (loadings) should be performed on all surfaces. While vacuum samples (concentrations) can be collected, neither HUD nor EPA can provide standards to interpret vacuum sampling results at this time. Until vacuum sampling standards have been established, wipe sampling is the preferred method.
1999 HUD 1012/1013 Final Rule [22].	Standards are reported as a loading for interior samples.
1996 EPA 402/404 Rule [4]	The type of dust samples to be collected, wipe (loading) or vacuum (concentration) are not explicitly defined in this document.
2001 EPA 403 Final Rule [1]	Dust-lead hazard and clearance standards are set as in loadings. In 40 CFR §745.65, it states "A dust-lead hazard is surface dust in a residential dwelling or child-occupied facility that contains a mass-per-area concentration of lead equal to or exceeding 40 $\mu g/ft^2$ on floors or 250 $\mu g/ft^2$ on interior window sills based on wipe samples." Dust-lead clearance standards are specified in 40 CFR §745.227 (e)(8)(viii) which were shown in Table J-5 [4].

Table J-8. Comparison of Compositing Rules from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Compositing Rules
1990 HUD Interim Guidelines [2]	Compositing was not addressed in this document.
1994/1995 EPA 403 Guidance [5]	Compositing was not addressed in this document.
1995 HUD Guidelines [3]	Samples are composited in the field. Separate samples are required from carpeted and hard surfaces; and from component sampled; and from each dwelling floor surface areas sampled in each room should be the same size. Interior sill and well sampling sizes are dependent on window characteristics, but should be similar from room to room; all subsamples should be inserted into the same tube. No more than four different wipes should be inserted into a single container.
1999 HUD 1012/1013 Final Rule [22]	Dust samples shall be collected and analyzed in accordance with standards established either by a State or Indian tribe under a program authorized by EPA in accordance with 40 CFR part 745, subpart Q, or by the EPA in accordance with 40 CFR 745.227 (both are part of the 1996 EPA 402/404 Rule [4]).
1996 EPA 402/404 Rule [4]*	Composites expressly permitted for clearance testing. Composite dust samples consist of at least two subsamples. Every component that is being tested shall be included in the sampling. Composite dust samples shall not consist of subsamples from more than one type of component.
2001 EPA 403 Final Rule [1]	A composite sample may contain from two to four subsamples of the same area as each other and of each single surface sample in the composite [40 CFR §745.63]

* 1998 EPA 403 Proposed Rule [24] included proposed amendments to the final Section 402 rules includes requiring the risk assessor to compare the composite sample to the clearance standard divided by the number of subsamples in the composite.

Table J-9. Comparison of Conflict of Interest Issues from HUD and EPA Clearance Guidance and Rule Documents.

Clearance Guidance Document	Inspection Conflict of Interest
1990 HUD Interim Guidelines [2]	To avoid potential conflict of interest, the abatement contractor should not conduct the final inspection. This should be done by a qualified inspector, industrial hygienist, or local public health official.
1994/1995 EPA 403 Guidance [5]	Clearance testing should be conducted by an organization that is independent of the organization that completed the abatement or interim controls.
1995 HUD Guidelines [3]	Inspectors should be independent of abatement contractor
1999 HUD 1012/1013 Final Rule [22]	Clearance examinations shall be performed by persons or entities independent of those performing hazard reduction or maintenance activities, unless the designated party uses qualified in-house employees to conduct clearance. An in-house employee shall not conduct both a hazard reduction or maintenance activity and its clearance examination.
1996 EPA 402/404 Rule [4]	EPA requested comment on whether to preclude individuals or firms conducting abatement activities from performing inspection and risk assessment activities, and from performing clearance procedures following an abatement. Although many public commentators supported a requirement that inspection, risk assessment and clearance procedures be conducted by individuals and firms independent of the individuals and firms conducting abatements, the final rule does not include such a requirement. Some of the reasons for not supporting a conflict-of-interest requirement were that the potential convenience and cost savings of hiring one firm, as opposed to two or three firms should not be denied a property owner. The Agency also noted that there may be instances in which, due to a regional scarcity of lead-based paint professionals, it may be cost prohibitive or logistically difficult for a building owner to hire two different companies. Nonetheless, the Agency believes that parties involved in lead-based paint activities should avoid situations of potential conflict of interest.
2001 EPA 403 Final Rule [1]	Addressed in the 1996 EPA 402/404 Rule [4].

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13. ABSTRACT (Maximum 200 words)

This report presented results from lead clearance testing activities that occurred between 1989 and 1999 under the 1990 HUD Interim Guidelines, which set dust lead clearance standards at 200, 500, and 800 $\mu g/ft^2$ for floors, window sills, and window troughs, respectively. Dust lead clearance results were obtained from the HUD's FHA and PHA Demo Studies, and Grantee Program; the Maryland Department of the Environment; the Atlantic City and Dover Housing Authorities; and the Cleveland Lead Hazard Abatement Center. Over 90% of individual clearance samples passed clearance. Only 67% of the housing units passed clearance on the first site visit. Eventually 87% of the housing units were known to have passed clearance. Floor samples had a smaller geometric mean lead loadings than sills, which in turn had a smaller geometric mean than troughs. Geometric mean lead loadings generally increased from the first site visit to the third site visit. The pairwise correlations between components during the first site visit were positive and significant. The simulated composite samples analysis results indicated that composite sampling is associated with a decrease of sensitivity if compared directly to the standards. Comparison of composite samples to two lower standards resulted in an increase in sensitivity.

14. SUBJECT TERMS
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